Earth Observing System

Mission Operations Concept Document

September 1996

PREFACE

This version of the Earth Observing System (EOS) Mission Operations Concept document updates the last issue (dated June 1995). It addresses the changes in the EOS mission and provides the latest information as derived from several EOS documents, notably the 1995 Reference Handbook, EOS Execution Phase Project Plan and EOS AM-1 documentation. The operations concepts embody ideas that have evolved from early EOS Mission Operations Working Group meetings, and AM-1 operations workshops, and the ESDIS operations working group.

This document describes operations concepts for the total EOS mission, which consists of several series of spacecraft over a 20-year period. It aims to give the reader a complete picture of EOS mission operations. Detailed operations concepts for individual spacecraft will be addressed in documentation to be generated by the flight projects. This document reflects the latest information on EOS and EOS operations as of June 1996.

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This document is available electronically on the EOS mission operations homepage at: http://esdis.gsfc.nasa. gov/ops/ops.html

ABSTRACT

The Earth Observing System (EOS) program involves the operation of numerous instruments on multiple spacecraft placed in polar and mid-inclination orbits in support of several disciplines within the Earth science user community. The EOS mission is composed of several series of flights, beginning with the EOS AM-1 flight from the AM series in 1998. The other EOS series include PM, LALT (Laser Altimetry) and CHEM (Chemistry) flights. Each spacecraft, with the exception of LALT, has a projected design lifetime of 5 years and an operational goal of 6 years. Spacecraft in the AM, PM and CHEM series will be replaced every 6 years to provide a total series lifetime of 18 years and a mission lifetime of over 20 years. The LALT spacecraft have a 3-year design lifetime and a projected operational lifetime of 5 years.

In response to the NASA Administrator's call for a smaller, faster, cheaper EOS mission, there is a current study involving the CHEM series, looking at several small spacecraft with one or two instruments, instead of the original baseline of medium spacecraft with three or four instruments.

Certain International Partners (IPs)--the European Space Agency (ESA), the Canadian Space Agency (CSA), and the National Space Development Agency (NASDA) and Ministry of International Trade Industry (MITI) of Japan--are planning Earth-observing missions that complement the National Aeronautics and Space Administration (NASA) program. They are also supplying instruments on selected EOS flights. The CSA is also providing an instrument on AM-1 and sponsoring two of the EOS interdisciplinary investigators. In addition to collecting data from these IP missions, EOS gathers data from other designated NASA Earth science missions, Landsat (beginning with Landsat 7), and future National Oceanic and Atmospheric Administration (NOAA) satellites.

The United States is developing a ground segment to meet the challenges of operating the various EOS spacecraft series. The EOS Data and Information System (EOSDIS) is the major ground system to support EOS. EOSDIS may be required to support as many as four spacecraft (one from each series), plus an additional spacecraft during crossover operations. EOSDIS is being designed with the necessary capabilities to provide the user community with flexible, efficient access to the large volume of Earth science data that will be processed and stored in the distributed archives and data centers to be developed for EOS.

This document describes the mission operations concepts to support operations of all the EOS spacecraft. It also discusses the concepts for supporting instrument operations from a science/user perspective. It shows how the potentially complex operations associated with the operation of a large number of spacecraft and instruments will be handled. The concepts described in this document will influence the end-to-end design of the EOS spacecraft, instruments, and ground system and will form the basis for the development of detailed procedures, requirements and scenarios.

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SECTION 1. INTRODUCTION

1.1 PURPOSE

This document describes the high-level mission operations concepts for the Earth Observing System (EOS). EOS is the centerpiece of the National Aeronautics and Space Administration's (NASA's) Mission to Planet Earth (MTPE) program, which is NASA's contribution to the U.S. Global Change Research Program (GCRP). EOS collects data from instruments on several spacecraft in support of disciplines within the Earth science user community. The EOS mission is composed of several series of flights beginning with the EOS AM-1 flight from the AM series in 1998. The other EOS series include PM, LALT (Laser Altimetry) and CHEM (Chemistry) flights. The spacecraft, except for those used on the LALT series, have a projected design lifetime of 5 years and a projected operational lifetime of 6 years. Spacecraft in the AM, PM and CHEM series will be replaced every 6 years for series lifetimes of 18 years and a mission lifetime of over 20 years. The LALT spacecraft have a design lifetime of 3 years, a projected operational lifetime of 5 years. The NASA MTPE missions are complemented by Earth-observing missions sponsored by the International Partners (IPs): the European Space Agency (ESA), the Canadian Space Agency (CSA), and the National Space Development Agency (NASDA) and Ministry of International Trade and Industry (MITI) of Japan. The IPs will supply instruments on EOS flights, and the CSA is also sponsoring two EOS interdisciplinary investigators.

The IPs listed above, through their activities in the International Geosphere-Biosphere Program and the World Climate Research Program (GCRP), coordinate with the U.S. GCRP to ensure proper development and use of an International Earth Observing System (IEOS). IEOS will enable scientists to obtain information on all major Earth system processes at many levels of detail. In addition to collecting data from the IP missions, EOS gathers data from designated NASA Earth science missions such as the Tropical Rainfall Measuring Mission (TRMM), Landsat (beginning with Landsat 7), Advanced Earth Observing Mission (ADEOS) II and future missions by National Oceanic and Atmospheric Administration (NOAA) satellites.

This document introduces science investigators, ground system personnel, and managers to current ideas about EOS mission operations. It will be maintained throughout the EOS development phase to steer and influence the operations requirements of the end-to-end system.

1.2 SCOPE

EOS is conceived and planned as an evolutionary system with a space-based observation capability, as well as a supporting ground system to be built up over time. Concepts are being developed so that additions to the EOS spacecraft complement will not significantly affect overall flight and ground-system operations. These concepts include: (1) instrument planning, scheduling, and operations, commanding of the spacecraft; and the subsequent evaluation of instrument housekeeping and engineering data; (2) science data processing, product generation, product quality assurance, data archival and distribution, and methods of enabling investigators to obtain access to the data ; and (3) flight operations concepts for the NASA EOS spacecraft. The term “flight operations” covers the overall coordination of instrument operations, spacecraft operations, operation of the space-to-ground communications links, interfaces between elements of the ground segment, and interfaces with the IPs. This document addresses items (1) and (3). “Mission operations”, as described in this document, does not include the processing beyond Level 0, archiving, distribution, and accessing of science data. Section 2 includes a high-level description of the EOS science operations elements in order to give the reader a complete view of the total system.

1.3 CONCEPT DEVELOPMENT PROCESS

The EOS Mission Operations Concept document, developed by the EOS Mission Operations Manager (MOM), provides high level concepts that integrate the operations of the space segment with those of the ground segment. The EOS Data and Information System (EOSDIS) Science Operations Concept, developed by the EOS Science Operations Manager (SOM), describes concepts for system-wide science operations, including the development of an overall processing policy regarding data requests, data acquisition, data processing, and data archiving. The integration of EOS operational elements with existing and future NASA support elements is essential before the capabilities of each segment can be fully used or maximum science returns provided. The EOS Mission Operations Concept and the EOSDIS Science Operations Concept define the concepts behind ground system operations. They also provide guidance for the development of more detailed operations concepts.

The EOS Ground System (EGS) System and Operations Concept, developed by the ESDIS Systems Management Office, integrates the Mission Operations Concept and the Science Operations Concept by providing an end-to-end view of EOSDIS operations as they support the flight mission and the science mission. It is intended as an additional resource to assist EOS investigators and other users in understanding EOSDIS capabilities and user interfaces on a lower level of detail. The flight project Operations Manager bears responsibility for The Spacecraft Operations Concept. The EOSDIS Core System (ECS) Operations Concept, developed by the ECS contractor, describes the concepts of the ECS and the interaction of segments within the ECS.

Under the current EOS organization, EOS mission operations issues are addressed through the ESDIS Operations Working Group (EOWG)) and spacecraft-specific operations meetings. The EOWG, which is chaired by the MOM, to provide an operations overview for the proper development of the EOS Data and Operations System (EDOS), EOS Communications (EBnet), and the Flight Operations Segment (FOS) of the EOSDIS. The EOWG is also directed to ensure that operations concepts support science policies. The MOM coordinates the operations of all EOS spacecraft and works with the flight project OMs to ensure that operational concepts and planning are consistent throughout the project. The flight project OMs are active members of the EOWG. The EOWG membership consists of line organization representatives in addition to the FOD, the FOS development manager, and the EDOS and EBnet managers. The OMs, assisted by the FOD, will chair the spacecraft-specific Operations Working Groups (OWGs), developing concepts and discussing spacecraft operations with the relevant instrument teams. The flight project OM is responsible for developing flight operations concepts and requirements for each flight in his/her series. Section 4 describes the roles of the MOM and the OMs in greater detail. The Inter-Project Agreements (IPAs) between EOS flight projects and ESDIS also defines the MOM and OM relationship for each series of spacecraft.

1.4 DOCUMENT ORGANIZATION

This document is organized into five major sections, as shown in Figure 1.4-1. Figure 1.4-1 also shows the breakdown of Section 3, which describes the major concepts of the integrated system for mission operations. A glossary of terms (Appendix B) provides the reader with additional information on selected EOS operational terms used throughout the document.

1.5 MISSION PHILOSOPHY AND GUIDELINES

EOS is a science mission. The basic mission operations philosophy is summarized by the statement "EOS Flies for Science." The primary goal of EOS is to provide usable, standard, and reliable data continually to support U.S. and international Earth science research. Mission operations must manage the spacecraft and the ground system so as to provide good data to the science/user community while remaining within the constraints on available resources. First, EOS must successfully launch, configure, calibrate, operate, and ensure the safety of the spacecraft on each flight. Second, the end-to-end design must incorporate adequate reliability within the space and ground segments to ensure the recovery of usable science data. These goals challenge the end-to-end system designers in the present budget-constrained and cost-driven environment.

Early and timely consideration of mission operations concepts are required in the development of an operationally sound and cost-effective system including spacecraft, instrument, and ground system operations during various phases. These phases include prelaunch operations, training and simulations, early orbit check-out and verification, normal spacecraft operations, analysis and distribution of the data received, and eventually the crossover operations replacing spacecraft at the end of their lives.

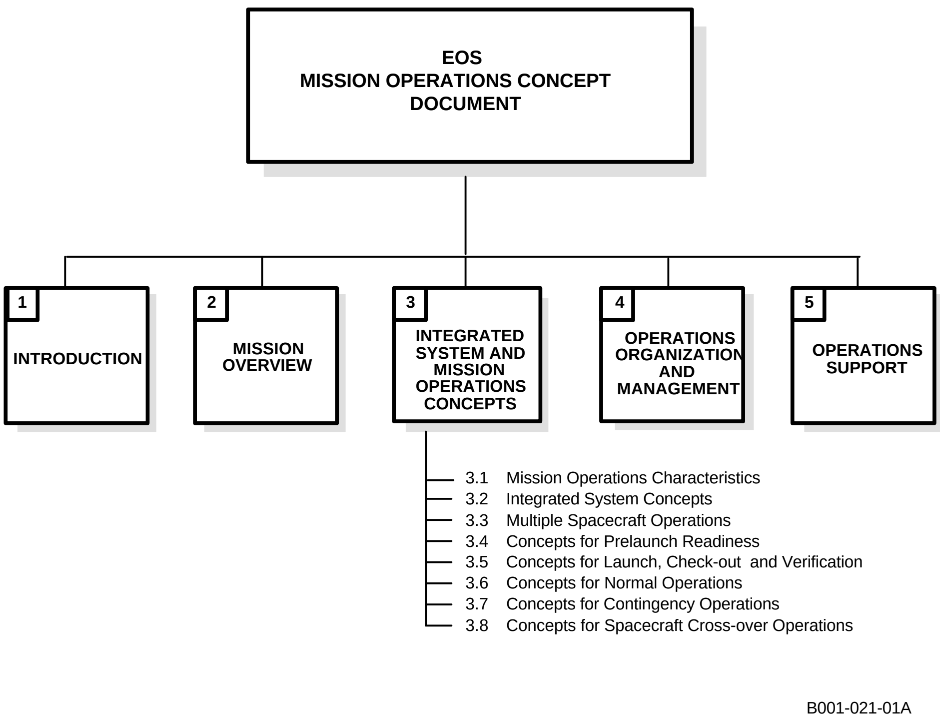


Figure 1.4-1 Document Organization

1.6 APPLICABLE DOCUMENTS

The following documents were referenced during the development of this document. The reader is encouraged to use present and future versions of these documents for further research. Most of the documents are available at the EOS library at GSFC, Building 32, telephone number 301-286-4406.

Earth Observing System (EOS) Reference Handbook, NASA/GSFC, 1993.

Flight Operations Segment ((FOS) Design Specification and FOS Database Design and Database Schema Specifications, NASA/GSFC, November, 1994.

Space Network (SN) Users Guide, STDN 101.2, Rev. 6, September 1988.

EOSDIS Science Operations Concept, December 1991 (Draft).

Project Plan for the Earth Observing System, May, 1995.

ECS System Design Specification, June, 1994.

EOS AM-1 CDR, January 1994.

FOS Operations Study Report, May 1994.

SECTION 2. MISSION OVERVIEW

2.1 MISSION TO PLANET EARTH

MTPE is NASA's contribution to the U.S. GCRP. The U.S. GCRP will establish a basis for national and international policy making regarding possible changes in the Earth's climate. MTPE is an evolutionary program that falls into two mission phases. Phase I consists of deployment and data collection from the multiple satellites that are currently in orbit or to be launched before the first NASA EOS spacecraft in 1998. These satellites, operated by NASA, other Federal agencies, and the IPs, make observations of global changes in advance of the EOS spacecraft. In addition, numerous air and ground observations of the Earth will be made during Phase I.

During Phase II, the global observations of Phase I will continue but will be augmented by more coordinated and comprehensive observations from spacecraft of the various EOS series over a 20-year period. Figure 2.1-1 shows a rough estimate of the vast amount of data that will be obtained by EOS spacecraft, various Phase I sources, and IP. The data will be processed and/or archived and distributed by the EOSDIS. EOSDIS will also receive and process data from coordinated ground campaigns, airborne observations, and ground truth/ground calibration campaigns.

2.2 EOS MISSION GOALS AND OBJECTIVES

The goal of EOS is to advance the scientific understanding of the Earth system components, the interactions among them, and the ways in which the Earth system is changing. Mission objectives in support of this goal are:

- To create an integrated scientific system observing the causes, processes, and effects of climate change and to enable multidisciplinary study of the Earth's critical, life-enabling, interrelated processes. Such processes include those of the atmosphere, the oceans, the land surface, the polar regions, the solid Earth; and the dynamic and energetic interactions between them.
- To develop a comprehensive data and information system (including data retrieval and processing) to serve the needs of scientists performing an integrated, multidisciplinary study of planet Earth.
- To acquire and assemble a global data base for remote sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes.

2.3 PRINCIPAL EOS MISSION REQUIREMENTS

- Establish a spaceborne observation capability lasting over 20 years.
- Maintain the continuity of essential global change measurements from ongoing and planned missions such as TRMM, the Upper Atmosphere Research Satellite (UARS), and the Ocean Topography Experiment (TOPEX)/Poseidon.
- Obtain at least one decade of overlapping, calibrated data from the full EOS Space Measurement System on NASA, ESA, and NASDA spacecraft.
- Characterize the highly variable aspects of the Earth's global system every 1 to 3 days.
- Make all EOS data readily and promptly available.

- Support the communication and exchange of the research findings based on EOS data or produced by EOS investigations.
- Support the overall U.S. GCRP.

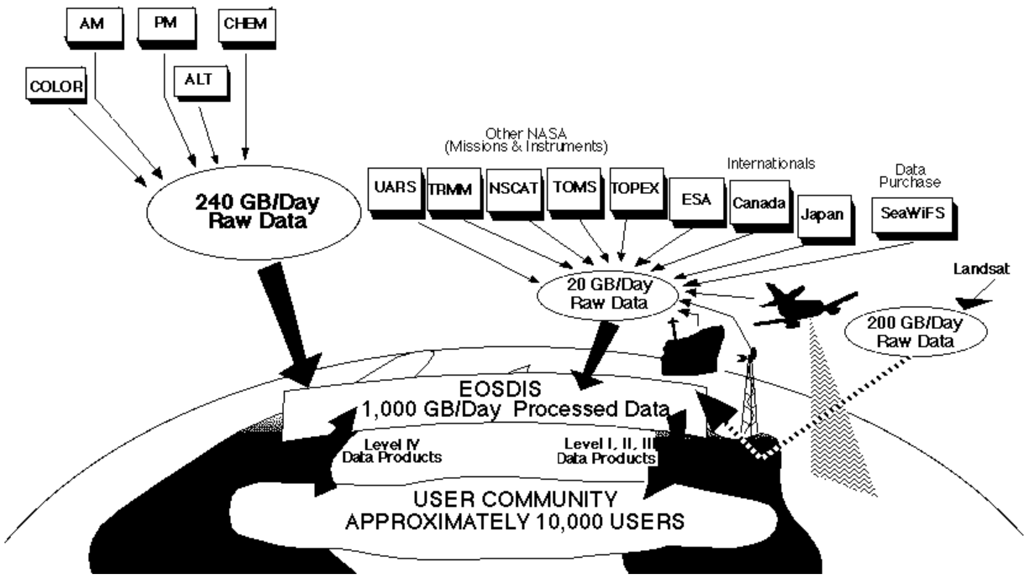


Figure 2.1-1 EOS Data

2.4 EOS MISSION MANAGEMENT PRIORITIES

Table 2.4-1 lists the priorities that have been established for the acquisition of EOS data to ensure that EOS resources (spacecraft and instruments) are properly used and managed.

Table 2.4-1 EOS Mission Management Priorities

PRIORITY	
↑	**OVERALL PRIORITIES**
	1. Platform Health and Safety. 2. Instrument Health and Safety. 3. Data to assist in a declared national or international environmental emergency.
	CALIBRATION/VALIDATION
	1. Special observations to enable cross-calibration of instruments. 2. Calibration of individual instruments. 3. Support of specific validation measurements.
	LARGE DATA ACQUISITIONS
	1. Acquisitions to continue long-term study of significant earth phenomena. 2. Acquisition of time-critical data on specific earth phenomena. 3. Support of large scale multi-investigator field experiments.
	SMALLER DATA SETS
	1. Specific requests by cooperating International Earth Observing System (IEOS) agencies, the total of which shall not exceed 10% of the available duty cycle of each instrument. 2. Support of modest or single investigator field experiements. 3. Acquisitions which have been scheduled two or more times and not successfully fulfilled.
	ALL OTHER DATA SETS

2.5 EOS MISSION CONCEPT

As shown in Figure 2.5-1, EOS consists of three major segments: (1) the EOS Space Measurement System (space segment); (2) the EOS Ground Segment, consisting primarily of the EOSDIS; and (3) the EOS Science User Community. The EOS Space Measurement System provides new capabilities for remote observations of the Earth, EOSDIS makes the data accessible to the scientific user community, and the user community uses the data derived from EOS to support scientific inquiries and to advise on climate policies. Figure 2.5-2 shows a high-level view of the EOS mission concept.

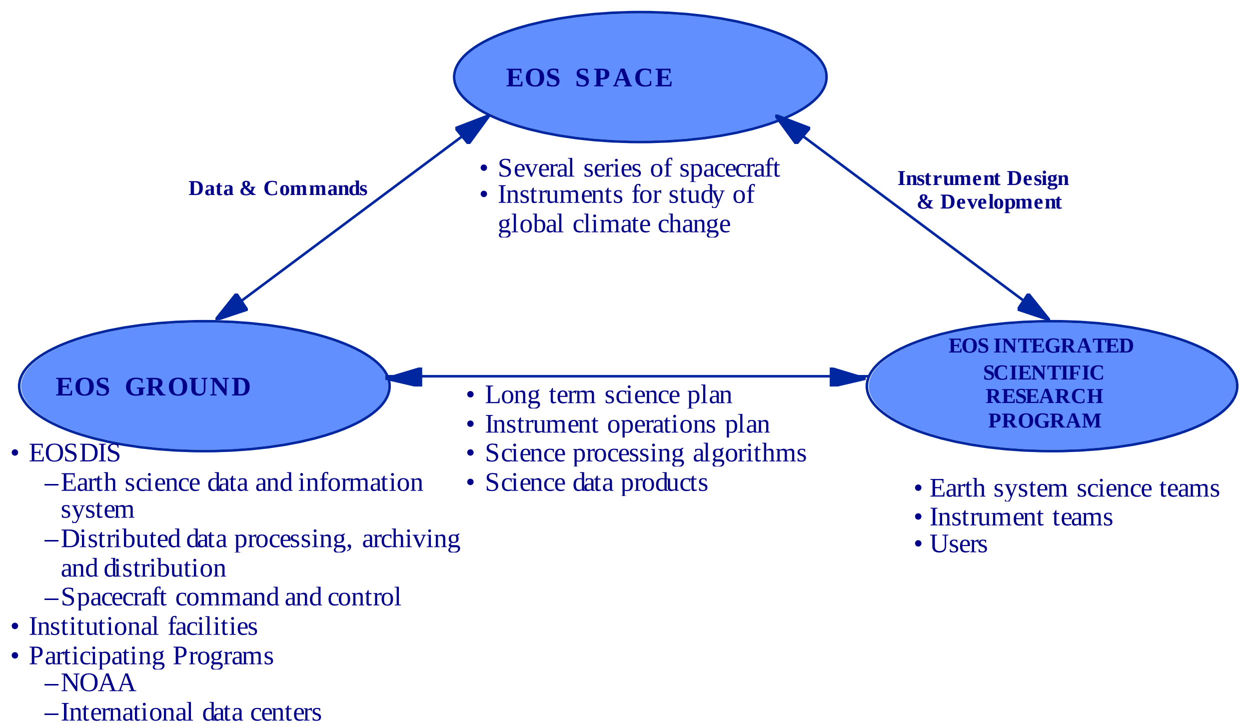


Figure 2.5-1 EOS Major Segments

2.5.1 EOS Science/User Community

EOS operations begin and end with the science/user community. Earth science researchers determine the observations to be made; Instrument Engineering Teams (IETs) build the instruments to collect the data; science teams plan and schedule the use of the instruments; other scientists provide the EOSDIS with the algorithms generating data products; EOSDIS provides mission operations and data processing; and the scientists perform quality assurance on the generated data products. Finally, users analyze the data from the EOS instruments, publish the results, and make recommendations to the global change research community.

The scientific instruments for the NASA spacecraft are divided into two classes; “Facility” and “Specific Facility” instruments measure variables useful in a wide range of scientific disciplines, whereas instruments supplied by the Principal Investigators (PIs) observe specific phenomena. The EOS investigators include the PIs and Co-Investigators (Co-Is) associated with PI instruments, the Team Leaders (TLs) and Team Members (TMs) associated with facility instruments, and the Inter-disciplinary Investigators (IIs) associated with two or more instruments. In addition, thousands of potential users, such as those from universities and private industry, may access and analyze data from the EOS.

The EOS Investigator Working Group (IWG) includes PIs, TLs associated with facility instruments, selected IIs, and the U.S. lead Co-Is associated with non-U.S. instruments. The EOS Program Scientist and Project Scientist co-chair the IWG, which consists of fourteen science panels. The chairpersons of each panel, the Program Scientist, and the Project Scientist make up the Science Executive Committee of the IWG. The IWG responsibilities are shown in Figure 2.5-3. In addition, the Earth Observing International Coordination Working Group (EO-ICWG) establishes a forum within which the United States and the IPs discuss, plan, and negotiate the international cooperation essential for the implementation of the International EOS (IEOS). The delegations to EO-ICWG are led by the Earth observations offices of the respective space agencies: NASA; the ESA; the Science and Technology Agency (STA), NASDA, MITI; and the CSA. Delegates to the EO-ICWG also include those from operational environmental monitoring agencies like the National Oceanic and Atmospheric Administration (NOAA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the Japan Meteorological Agency (JMA), and the Atmospheric Environment Service (AES). The EO-ICWG meets two or three times per year to address technical issues and issues of policy, including payloads, operations, data management, and interfaces between the instruments. When necessary, the EO-ICWG will provide recommendations on international issues to promote optimum Earth observations.

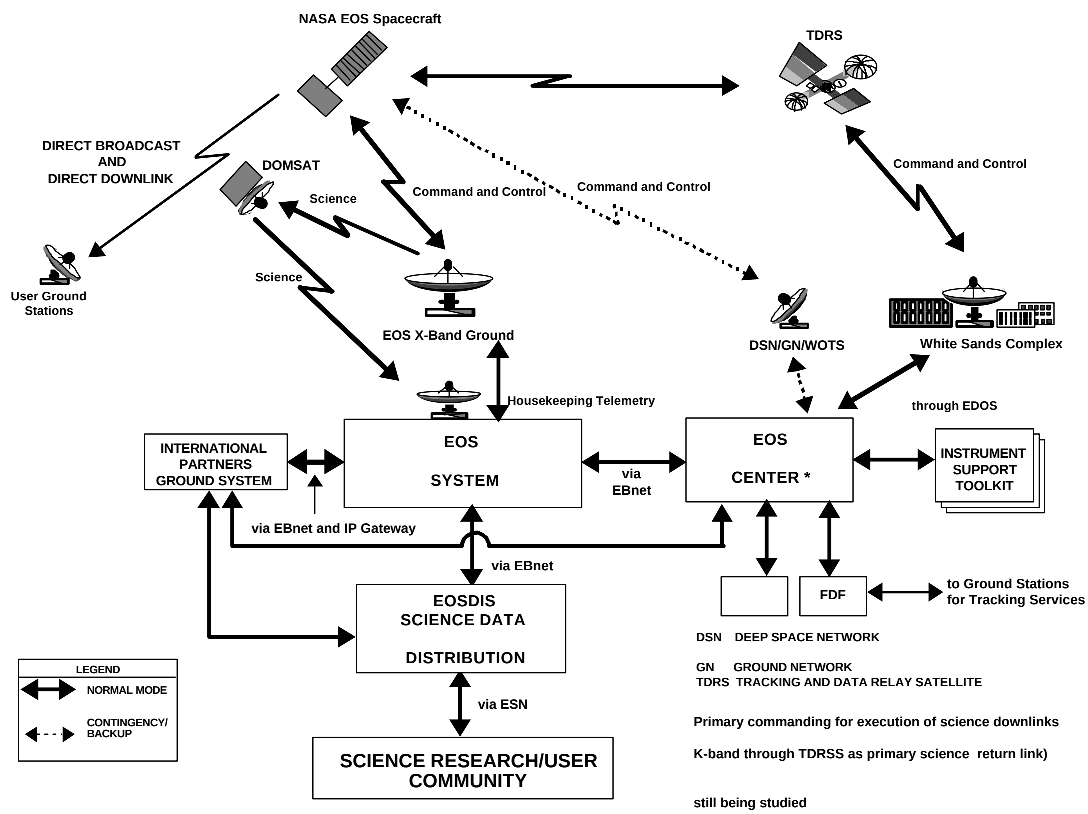


Figure EOS Operations General

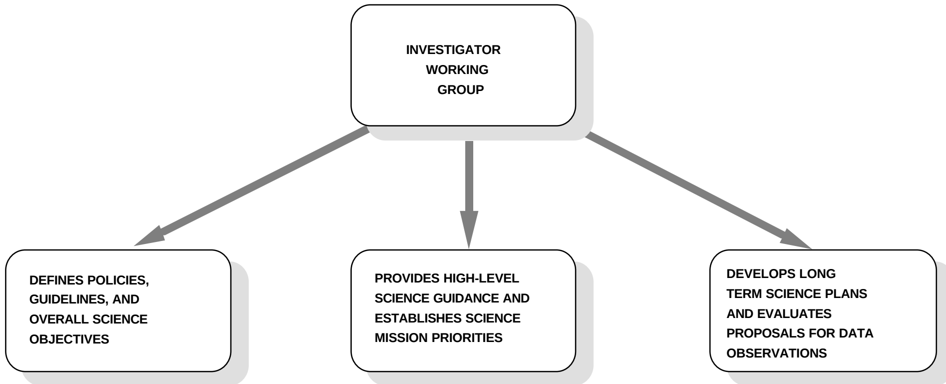


Figure 2.5-3 Summary of IWG Responsibilities

EOS is characterized by a large, geographically dispersed science/user community in a broad range of scientific disciplines and with a broad range of operations experience and computer systems skills. The community has three categories of users. The first category, EOS investigators, includes the investigators and research staff funded after evaluation of the responses to the NASA EOS Announcement of Opportunity. This group includes instrument PIs and Co-Is, facility instrument TLs and TMs, and IIs. The second category consists of the large group of scientific users unaffiliated with the EOS, such as scientific researchers located at various government agencies, education centers, and commercial organizations in both the United States and abroad. The third category consists of users who operate and maintain the many elements that make up the EOSDIS.

2.5.2 Space Measurement System

The space segment of the EOS Space Measurement System consists of a new series of predominantly polar-orbiting spacecraft. Table 2.5-1 summarizes the U.S., ESA, and NASDA missions as currently planned. The major scientific objectives of each U.S. EOS series are described in Table 2.5-2.

2.5.2.1 EOS Instruments

Many instruments have been selected and will be selected for the U.S. EOS series of spacecraft. Table 2.5-3 shows these instruments, the institutions proposing them, and their current or proposed average and peak data rates.

2.5.2.2 Configuration of Flights

The four series of U.S. EOS spacecraft will each carry the instruments appropriate for their measurement objectives. Figure 2.5-4 shows the complement of instruments planned for each of the four series and individual spacecraft launch dates.

During the 20-year plus operational lifetime of EOS, as many as four spacecraft (one from each series) will simultaneously perform normal operations. In addition, there may be two spacecraft from the same series in orbit during spacecraft crossover and replacement periods of up to 6 months.

Table 2.5-1 Summary of the Planned U.S. EOS Spacecraft

U.S. Earth Observing System (EOS)				
Spacecraft Series	No. of Spacecraft	Launches (Tentative)	Nominal Design Lifetime (Years)	
			Per Spacecraft	Series
AM	3	June 1998, 2004, & 2010	5	15
PM	3	December 2000, 2006, & 2012	5	15
LALT	TBD	June 2003, 2009, & 2015	5 (goal)	15
CHEM	TBD	December 2002, 2008, & 2014	5	15

Polar-Orbit Earth Observation Mission (POEM)*		
Spacecraft	Launch	Nominal Lifetime (Years)
ENVISAT SERIES	June 1998	5
METOP SERIES	2000	TBD

* European Space Agency

Japanese Earth Observing System (JEOS)		
Spacecraft	Launch	Nominal Lifetime (Years)
ADEOS	February 1996	TBD
ADEOS IIA	1999	TBD
ADEOS IIB	TBD	TBD
TRMM-2	2000	TBD

Table 2.5-2 Science Objectives For EOS Series

EOS SERIES	MAJOR SCIENCE OBJECTIVES
AM	Characterization of the terrestrial and oceanic surfaces Clouds, aerosols, and radiation Radiative balance Sources and sinks of greenhouse gases
PM	Cloud formation, precipitation, and radiative balance Terrestrial snow and sea ice Sea-surface temperature and ocean productivity
LALT	Ice sheet mass balance
CHEM	Atmospheric chemical species and their transformations Ocean surface stress

Table 2.5-3 EOS Instruments

INSTRUMENT ACRONYM	INSTRUMENT NAME (INSTITUTION)	DATA RATE* (kbps) AVERAGE	PEAK
AIRS	Atmospheric Infrared Sounder (JPL)	1440.0	1440.0
AMSU	Advanced Microwave Sounding Unit (JPL)	3.2	3.2
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer (MITI/Japan)	8300.0	89200.0
CERES	Clouds and Earth's Radiant Energy System (LaRC)	10.0	10.0
ODUS	Ozone Dynamics Ultraviolet Spectrometer (Japan)	10.0	13.5
EOSP	Earth Observing Scanning Polarimeter (GISS/GSFC)	44.0	88.0
GLAS	Geoscience Laser Altimeter System	206.0	206.0
HIRDLS	High-Resolution Dynamics Limb Sounder (NCAR/Oxford Univ. England)	50.0	50.0
LATI	Landsat Advanced Technology Instrument	26500.0	26500.0
MHS	Microwave Humidity Sounder (NOAA)	4.2	4.2
MISR	Multi-Angle Imaging Spectro-Radiometer (JPL)	3800.0	6500.0
MLS	Microwave Limb Sounder (OH)	100.0	100.0
MODIS	Moderate-Resolution Imaging Spectrometer (GSFC)	6200.0	11000.0
MOPITT	Measurements of Pollution in the Troposphere (Univ. of Toronto/Canada)	25.0	40.0
TES	Tropospheric Emission Spectrometer	3240.0	19000.0

*Rates beyond AM-1 are subject to change.

2.5.2.3 Launch and Spacecraft Orbit

EOS spacecraft will vary in size and complexity and hence will be placed in orbit using various launch vehicles. The AM-1 spacecraft will be launched on an Intermediate Expendable Launch Vehicle (IELV) from the Vandenberg Air Force Base (VAFB) in California. Subsequent AM, PM, LALT, and CHEM spacecraft will be launched on Medium ELVs (MELVs). The AM, PM, and CHEM spacecraft will be inserted into a near-circular, sun-synchronous, 705 km orbit at the equator with an inclination of approximately 98.2 degrees. LALT spacecraft will also be inserted into a near-polar orbit, with an altitude to be determined. The descending node-crossing time for the AM-1 spacecraft is approximately 10:30 a.m. The node-crossing times for the subsequent AM spacecraft, as well as the LALT spacecraft, are to be determined. The ascending node-crossing times for the PM and CHEM series are approximately 1:30 p.m. and 1:45 p.m. respectively. Since the AM series primarily observes surface features, the morning crossing time was chosen because cloud cover during that period is minimal. An afternoon crossing time was chosen for the PM series because it is best for meteorological forecasting. Furthermore, since the instruments of both the AM and PM spacecraft focus on characteristics of the terrestrial surface and atmosphere, measurements at different times of the day make it possible to study diurnal variations in these features. The ground tracks of the AM, PM, and CHEM spacecraft orbits repeat every 16 days, or every 233 orbit revolutions.

2.5.2.4 Spacecraft Design Philosophy

The rescoping of the EOS Program in 1993, due to budgetary limitations, resulted in the decision to provide a common spacecraft bus for the PM and CHEM spacecraft following AM-1. Development of a common spacecraft bus increases the payload flexibility and simplifies the instrument design by use of a known interface. To minimize the impact to current launch schedules and costs, the AM-1 design will be maintained and therefore will be unlike that of subsequent EOS spacecraft.

A Cooperative Agreement Notice [CAN] to solicit proposals from the aerospace community has been issued, with the EOS Chemistry suite of instruments being used as a ‘straw man’. NASA is seeking to capitalize on existing industry and government investments that may reduce future mission costs. Some low cost satellites have already been developed which may meet the needs of EOS missions such as EOS Chemistry. NASA’s Goddard Space Flight Center [GSFC] will represent NASA in joint [and equal investment] cost studies with several recipients with an overall goal of holding spacecraft costs to the lowest possible cost.

Spacecraft design will use lessons learned from previous spacecraft as applicable. An operational philosophy in the design of EOS spacecraft will be to require a minimum of ground control and interaction for optimal spacecraft subsystem operations. Communications with EOS spacecraft will be limited by the number of EOS ground stations available. In addition, other spacecraft’s’ demands for the resources of the Space Network/Tracking and Data Relay Satellite System (SN/TDRSS) (see Section 2.5.2.5) during the EOS’s operational lifetime may limit the amount of real-time space-to-ground interaction TDRSS can provide. In these circumstances the spacecraft cannot afford to rely on directions from the ground system in reacting to any anomalies. Therefore, each EOS spacecraft will be designed to operate with as much autonomy as possible during normal operations.

The spacecraft may make use of onboard monitoring functions similar to those used on current spacecraft (e.g., UARS). Selected telemetry points (settable from the ground) from individual subsystem components are monitored by the spacecraft onboard computer. These points are compared to pre-established thresholds or limits, which can also be set or overridden if necessary via ground commands. Should an anomalous spacecraft condition occur, the spacecraft will identify the likely cause and switch to a redundant path or function within the subsystem. If the anomaly continues, the spacecraft will revert to a degraded mode of operations. Spacecraft subsystem housekeeping data are downlinked to allow ground-based evaluation of the spacecraft performance and investigation of the anomalous condition. Under certain conditions, when an anomaly jeopardizes the spacecraft’s life, the spacecraft will automatically place itself in a "safe mode" in which only the critical components operate to maintain the spacecraft’s viability and safety.

Another spacecraft design concept that will be particularly useful in some EOS spacecraft (i.e., AM, PM, and CHEM flights) is modularity in the spacecraft subsystems. Equipment modules (EMs) will be used so that much of the spacecraft buildup can occur in parallel. Each EM is built and its functions tested separately, and then integrated with the spacecraft structure. EMs will, when possible, contain equipment from one subsystem to facilitate Integration and Testing (I&T) and will minimize the harness and connections required among EMs.

More detailed concepts regarding spacecraft design can be found in the documentation for each EOS spacecraft.

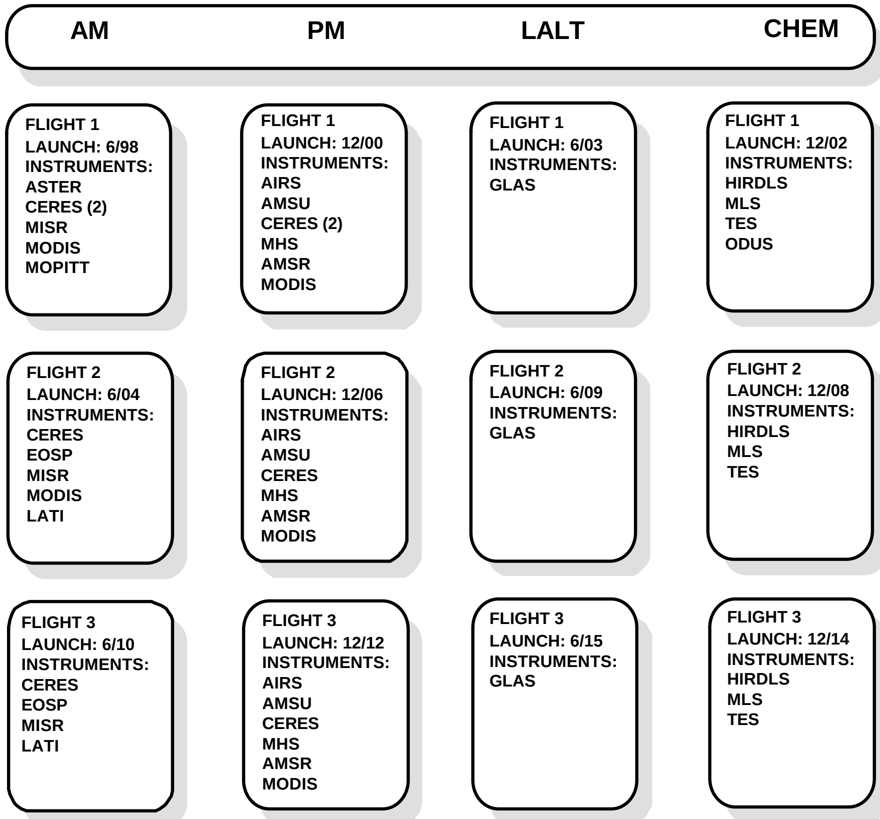


Figure 2.5-4 EOS Instrument Configuration

2.5.2.5 Space-to-Ground Communications

Recent Level 1 Requirements changes to the EOS Project Plan have shifted primary communications for EOS spacecraft from Ku-band through the SN/TDRSS to X-band using dedicated EOS ground stations. The use of X-band provides several advantages over the traditional TDRSS K-band downlinks. From the design point of view, the elimination of a deployable High Gain Antenna (HGA) reduces spacecraft complexity. Removal of the HGA also increases the mass and volume margins of the spacecraft. From the ground system point of view, switching to the use of dedicated ground sites for EOS data receipt eliminates contention for TDRSS K-band resources with other K-band users. The ground sites will also provide S-band command and control links, although all EOS spacecraft will retain their capabilities for interfacing with the TDRSS for command and control. Concepts surrounding the use of X-band ground sites continue to evolve through trade studies and working group meetings. In addition, EOS spacecraft will use the Ground Network (GN)/Wallops Orbital Tracking Station (WOTS) for emergency operations. Figure 2.5-2 shows the planned links under normal conditions and during contingencies.

Because the AM-1 spacecraft design is mature (critical design review complete), AM-1 will use the SN/TDRSS for its primary space-to-ground communications. It will, however, have an X-band downlink capability that will be used in the event of a failure in the primary communications system. Two X-band stations, located in Alaska and Norway, will provide back-up science support to AM-1.

Forward Link:
EOS spacecraft after AM-1 will have the capability to use either EOS ground stations or TDRSS for

communicating commands to the spacecraft. EOS spacecraft will use both the S-band Multiple Access (SMA) and S-band Single Access (SSA) services on TDRSS. The AM-1 spacecraft will normally use a spacecraft High Gain Antenna (HGA) to receive commands and command loads through a TDRS Single Access (SA) antenna via S-band. The spacecraft can use the TDRS Multiple Access (MA) antenna during periods when the SA is unavailable. S-band omnidirectional antennas are used for initial spacecraft acquisition after launch before the HGA is deployed, for contingency commands through the TDRSS, or for emergency commands through the ground network (GN/WOTS).

Return Link:
Science data will normally be recorded on high-rate solid state recorders and played back via the X-band to the ground (AM-1 will use K-band through the spacecraft HGA and TDRSS as its primary link). Science data may also be transmitted in real-time as needed. Domestic Satellite (DOMSAT) links will be used to transfer the large volumes of data from an EOS ground station to the EDOS facility. Housekeeping data will be transmitted in real-time to EOS ground stations via S-band or through the TDRS S-band omnidirectional antennas. Housekeeping data may also be transmitted through omnidirectional antennas using emergency links to the GN/WOTS.

Alternative Science Data Links:
In addition to the direct playback of science data to specified sites, selected EOS spacecraft will have the capability to downlink instrument data directly to users via X-band. A Direct Broadcast (DB) service will deliver selected data sets (MODIS data for AM-1) in real-time to the users who are within view and have 3-meter antenna dishes. EOS spacecraft may be programmed to inhibit DB (X-band) downlink over designated ground antenna locations if interference is deemed a problem. The AM-1 spacecraft can, in addition, use a Direct Downlink (DDL) capability to transmit Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data in real-time as scheduled by the ASTER Instrument Control Center (ICC) in Japan.

2.5.3 Ground Segment

Satisfying the EOS program objectives requires a data and information system that facilitates and encourages multidisciplinary and interdisciplinary investigations. The EOS ground segment consists of EOSDIS and NASA institutional facilities as well as elements from other U.S. government agencies, the IPs, and user-support facilities. Figure 2.5-5 focuses on the ground segment components of EOS.

2.5.3.1 EOS Data and Information System

The EOSDIS will serve as NASA's Earth science data system. It will manage information and process, archive, and distribute NASA Earth science data. The EOSDIS will provide command and control, data processing, product generation, and data archiving and distribution services for the U.S. EOS spacecraft. It will also archive and distribute data for other Earth science missions as directed by NASA Headquarters.

Its commitment to provide a long-term database of usable scientific information to the various user communities distinguishes EOSDIS from current remote-sensing data systems. EOS data products will be used by a full spectrum of scientists and the public throughout the life of the program (20 years or more) in the decades to follow. Standard, reliable data products, essential in distinguishing natural and anthropogenic phenomena, give the scientific community the ability to derive and validate models of processes on local, regional, and global scales.

EOSDIS has a distributed, open-system architecture, so that EOSDIS elements can be distributed to various locations to take advantage of different institutional capabilities and areas of science expertise. Although EOSDIS is widely distributed physically, it will appear a single logical entity to the users.

EOSDIS supports three major functions: flight operations, science data processing and distribution, and communications and system management.

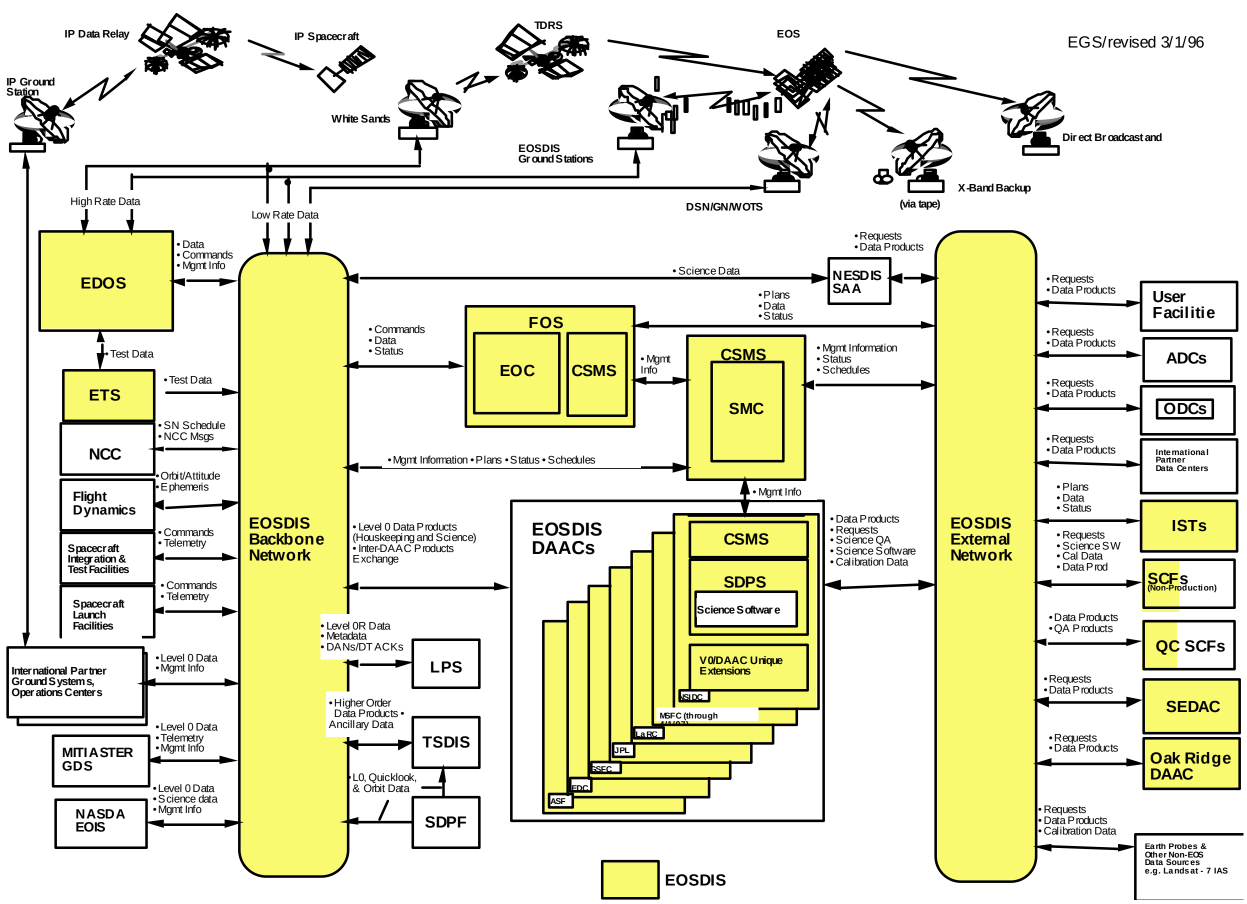


Figure 2.5-5 EOS Data And Functional Interfaces

Flight Operations:
Spacecraft and instrument operations will be performed at the GSFC EOS Operations Center (EOC), Instrument Control Centers (ICCs) as required, and using Instrument Support Toolkits (ISTs) and additional capabilities located at PI/TL home institutions. EOS ground stations, EDOS, EOS Communications (EBnet), and NASA institutional systems provide the flight operations support linking the EOC and the spacecraft.

The Flight Operations Team (FOT) at the EOC will perform all EOS spacecraft subsystem operations and operations coordination for its instrument complements. The EOC will provide the capability for monitoring of spacecraft health and safety, mission planning and scheduling, spacecraft commanding, instrument command support, and overall mission operations. The EOC will operate most instruments (see Section 3.3.2) in coordination with instrument personnel [PIs/TLs and Instrument Engineering Teams (IETs)] using ISTs. The allocation of all aspects of instrument operations (e.g., planning and scheduling, command generation, and instrument monitoring) will be negotiated with the instrument teams and established preflight. These functional allocations may change during the flight as particular aspects of instrument operations become better defined (i.e., functions that are found to be more complex than anticipated). The FOT will support the sustaining engineering services and maintenance for the spacecraft, using spacecraft analysis software tools and a spacecraft simulator to investigate anomalies and test possible procedural workarounds. All communications to the spacecraft and instruments go through the EOC, which coordinates spacecraft command and telemetry with EDOS, EBnet, EOS ground stations and external systems such as the Network Control Center (NCC) and the Flight Dynamics Division (FDD).

The EOS ground segment will establish ICCs only as-needed. For the AM-1 flight, there will be only one ICC (for ASTER), which will be located in Japan. The ASTER ICC is not an EOSDIS developed ICC; it is part of the Japanese ASTER ground data system and used to perform their instrument operations. ICCs will normally be used by instruments with complex operations.

The design and functions of the ICCs and ISTs are based on the concept of distributed operations. Instrument personnel plan and schedule instrument activities, generate instrument commands, monitor instrument performance, analyze health and safety, perform instrument troubleshooting, and maintain onboard instrument software.

The PIs and the TLs are ultimately responsible for the operation of their instruments. They participate in the operation of their instruments remotely, through an IST, or from an ICC. A software toolkit implemented on an investigator workstation will provide the IST basic functionality. The IST gives the investigator access to data and displays from the EOC and allows an investigator to generate and send instrument activity schedules to the EOC as appropriate. The ISTs support instrument planning and scheduling, health and safety monitoring, performance monitoring, sustaining engineering, and anomaly investigation. ISTs will usually be located at the Science Computing Facilities (SCFs) of each PI/TL. The Instrument teams support flight operations, through use of the ISTs, by analyzing long-term trends, updating flight software, calibrating instruments, and evaluating and resolving problems with the instruments.

The current baseline is for EOS ground sites to provide the primary communications link between EOS spacecraft (except the AM-1) and the EOSDIS (see Section 2.5.2.5). The locations of the sites are yet to be determined. EDOS will provide real-time forward-and-return-link data-handling services between the EOS ground stations [or, for TDRSS, the White Sands Complex (WSC)] and the EOC to support command and control and health and safety monitoring.

EBnet will provide forward and return-link transport services for all mission-critical EOS operational data. Functionally, EBnet will provide communications services among the mission-critical elements of the EOS ground system [including the EOS ground stations, White Sands Complex (WSC), EDOS, EOC, and the ICCs]. NASA Communications (Nascom) will transfer information between the NCC and the EOC and link the Nascom Message Switching Unit (MSU) with the GN, and WOTS, using both EBnet and existing Nascom lines for contingency operations. Nascom will also provide the dedicated voice circuits needed for flight operations.

Science Data Processing and Distribution:
The science data processing and distribution functions will be performed by EDOS and the Distributed Active Archive Centers (DAACs), and supported by the SCFs and the User Support Offices located at each DAAC. Table 2.5-4 shows the DAACs and each one's scientific specialty. Operations concepts involving these facilities will be found in EOS Science Operations Concept. A high-level description of the functions is provided below to provide the reader with an end-to-end view of EOSDIS. EDOS will perform initial data processing (Level 0), and send different subsets of the EOS data stream to each DAAC. Level 0 processing consists of packet time- order sequencing, data transmission artifact removal, data overlap removal and data quality checking. EDOS also provides a rate-buffered service to selected customers such as the NOAA facility in Suitland, Maryland. The rate-buffered service will make raw data available to NOAA for delivery within 5 minutes of receipt of the entire data set for a TDRS contact period. The Level 0 data are sorted by instrument and sent as production data sets to the DAACs responsible for the higher level processing of data from selected instruments. Delivery of data to the IP facilities is discussed in Sections 2.5 and 3.2.1. Data processing functions at EOSDIS Levels 1 through 4 (science data processing, product generation, product distribution, and archival) will be performed by the appropriate DAACs.

EOSDIS will provide a set of data ingestion, processing, and distribution services to each DAAC. The DAACs will use these services to process data from the EOS instruments into Level 1-4 data products. Each DAAC will also provide short-term and long-term storage for EOS and other Earth-observing missions and other related data, software, and results, then distributes the data to EOSDIS users. EOSDIS will provide the DAACs with distributed data, information management functions, and user services tools to give users a comprehensive view of all EOS data holdings. These service tools include a catalog system to assist users with data selection and ordering.

Table 2.5-4 Distributed Active Archive Centers

Distributed Active Archive Center	Discipline
University of Alaska - Fairbanks	Sea Ice, Polar Process Imagery
EROS Data Center [EDC]	Land Processes Imagery
Goddard Space Flight Center [GSFC]	Upper Atmosphere, Atmospheric Dynamics, Global Biosphere, Geophysics
Jet Propulsion Laboratory [JPL]	Ocean Circulation, Air-Sea Interaction
Langley Research Center [LaRC]	Radiation Budget, Aerosols, Tropospheric Chemistry
Marshall Space Flight Center [MSFC]	Hydrology

University of Colorado	Cryosphere
Oak Ridge National Laboratory	Biogeochemical Dynamics
Consortium of International Earth Science Information Network [CIESIN] Socio-Economic Data and Applications Data Center [SEDAC]	Socio-Economic Data and Information

The science investigators at their SCFs will develop and update the algorithms and science software used by the DAACs. The DAACs will integrate science algorithms within the system, maintain configuration control, and ensure that metadata conform to the algorithms used. “Metadata” describe the content and processing history of the EOS data and products. In addition, integrated and tested software will be sent to the appropriate DAACs for further integration and testing before use. To facilitate this process, the PIs/TLs will be provided with a data processing toolkit emulating the DAAC processing environment. The DAACs will monitor and ensure product development, using the algorithms and software received. However, Quality Control (QC) SCFs will also have special software to enable the investigators, responsible for standard product algorithms, to perform scientific quality control of their products.

The DAACs will receive science software, algorithms, science data, ancillary data, and correlative data for processing and will archive and distribute the processed data products and browse data products as requested. “Browse data products” consist of concise information provided in response to preliminary user requests to enable the users to select only the data relevant to their research. Standard and special data products will be distributed to the EOS scientists and other authorized users either upon request or by subscription.

Due to the geographically distributed nature of EOS data processing, product generation, and data archival, an efficient information management system is needed to allow users to search archives rapidly, browse through the contents, identify the data needed to support their research, and request delivery of data or products. EOSDIS will provide a single point of access ("one-stop shopping") at which users may obtain information regarding data in EOSDIS and external archives. EOSDIS will provide master directories, catalogs, inventories, documentation, and user help. User requests for data acquisition and processing will be accepted and forwarded to the appropriate DAACs. These functions will be especially helpful to the IIs, which may request data from instruments located at multiple DAAC sites.

User Support Offices will be located at each of the DAACs and will help users understand the data products of that DAAC. These offices will obtain information on evolving requirements, assist in problem resolution, and support the investigators in algorithm development.

Communications and System Management:
Various system-wide services are needed to support each of the geographically distributed elements of the EOSDIS and to support communications to user facilities. The interconnection of the EOSDIS elements requires a secure, high-bandwidth network, functioning in a controlled manner, to enable the various elements to support one another in a timely fashion and to support communication with the satellites. The EOSDIS uses two networks; the EOSDIS Backbone Network (Ebnet), and the NASA Science Internet (NSI). Ebnet interfaces all internal elements while NSI satisfies the external network interface functions. The external network will provide easy connectivity for IST’s, SCI’s, International partners and other general users.

The System Monitor and Coordination Center (SMC) will provide a focal point for system-wide management of EOSDIS operations through configuration control, high-level scheduling, performance and security management, data accounting/data accountability, and directory and reporting services. The SMC will support and maintain EOSDIS policies and procedures regarding instrument and ground event scheduling; including directives for scheduling instrument data collection, data processing and reprocessing, data retrieval, and data distribution. To accomplish effective coordination between the SMC and other EOSDIS sites/elements, Local System Management services (LSM) will be available at each of the sites. The LSM toolkits will provide the means by which the SMC monitors the ground operations of each site/element. The LSMs provide a communications path between sites/elements and the SMC to exchange management and operations information. The LSMs provide local management and operations personnel with the means to control and monitor their ground resources and ground operations activities in general.

2.5.3.2 EOSDIS Evolution

User needs for EOSDIS will become more clearly understood as users work with and provide input into early versions of the system. User requirements will change over time as new technology on information systems, database and information management, computer processors, and networks continues to emerge. For EOSDIS to succeed over its lifetime, its design and implementation must be responsive and flexible to change while continuing to support ongoing operations and user services. Development and prototyping will continue throughout the life of EOSDIS.

The initial development of EOSDIS has been structured to ensure that the EOSDIS design incorporates lessons learned from user experience with existing NASA data sets and the results of prototyping efforts in various EOSDIS elements. On-going prototyping and user feedback will be incorporated into new versions of EOSDIS following successful demonstration to and acceptance by the users. Implementation of new EOSDIS versions will be accomplished with minimal disruption to current EOSDIS operations.

The first major activity in the development of EOSDIS is Version 0. The main task during Version 0 is to gain experience in handling large Earth science data sets by turning existing data sets into more user-friendly formats. This task has the added advantage in that existing data sets are more widely accessible to the science community. Major Version 0 goals are to: (1) provide electronically networked DAACs; (2) improve access to current data products, develop commonality among data systems at the DAACs, and provide a more unified view of Earth sciences to the user community; (3) provide an interoperable catalog system to allow users to select data products from multiple DAACs; (4) develop prototype technologies relevant to EOSDIS; and (5) adopt provisional data exchange standards, protocols, and guidelines.

EOSDIS Version 1 will provide: (1) the operational functions of information management, (2) algorithm development and (3) product generation, and data archiving and distribution. Version 2 will provide: (1) full functionality, (2) the support for the EOS AM-1 spacecraft operations, (3) data from Earth science instruments on other spacecraft such as TRMM, and (4) the services already provided by Version 1. Subsequent versions are scheduled to support the full functionality and capacity required by the EOS space segment.

2.5.3.3 Institutional Facilities

The NASA institutional capabilities include the TDRSS, GN, WOTS, Nascom, NCC, and the FDD. The space-to-ground communications were discussed in Section 2.5.2.5. The institutional communications services for the ESN (EBnet, NSI) were discussed in Section 2.5.3.1 (*Communications and System Management*).

Nascom provides communications services between the EOC and the NCC and provides some connectivity with GN/WOTS. EBnet provides the mission-critical communications. The NCC provides the operational management and control of the TDRSS. The NCC schedules TDRSS resources and maintains long-term and near-term schedule data bases. The NCC will be enhanced as needed to handle the increased TDRSS scheduling complexity due to the expansion of the WSC and the demands of the missions for the next decade.

The FDD will provide orbit and attitude computational services and navigation data in support of EOS. Prelaunch services include mission design analysis, trajectory analysis, sensor analysis, and operations planning. Operational support services include orbit and attitude determination, anomaly resolution, maneuver planning and support, sensor calibration, and generation of planning and scheduling data products. During routine on-orbit operations, the TDRSS Onboard Navigation System (TONS) will be used for orbit determination on the AM-1 spacecraft. The FDD will perform verification of the TONS' initial and ongoing performance. A large portion of the services provided by the FDD will be performed within the EOC, using the concepts provided by FDD in support of "ops 2000" philosophies.

2.5.3.4 Affiliated Data Centers and Other Data Centers

The Affiliated Data Centers (ADCs) and Other Data Centers (ODCs) are non-EOS data centers with which agreements will be made to gain access to non-EOS data or to non-EOSDIS services required by EOS. ADC services include aiding in algorithm and software development for data processing. The ADCs will also receive selected EOS data sets from the DAACs. One example of a currently planned agreement with an ADC is with the NOAA/National Environmental Satellite, Data, and Information Service (NESDIS). NOAA is planning to process operational data in near real-time. EDOS will generate EOS raw data packets from a selected set of instruments (CERES for AM-1) for use by the NOAA facility in Suitland, Maryland. NOAA will also provide correlative data to EOSDIS for use in higher level processing. The ODCs will provide access to existing Earth science databases and correlative data.

2.5.3.5 Global Change Data and Information System

The ESDIS Project is currently involved in discussions for the development of a Global Change Data and Information System (GCDIS). GCDIS will include interfaces among NASA and other government agencies. A forum for the development of the GCDIS is currently being defined.

2.6 INTERNATIONAL PARTICIPATION

ESA, EUMETSAT, CSA and NASDA are planning Earth observing missions (e.g., the Environmental Satellites (ENVISAT), the Meteorological Satellites (METOP, ADEOS, and RADARSAT) that complement the NASA EOS program. In addition, EUMETSAT is providing the Microwave Humidity Sounder (MHS) instrument to be flown on PM-1; MITI of Japan is providing the ASTER instrument on the AM-1 spacecraft; and the CSA is providing the Measurement of Pollution in the Troposphere (MOPITT) instrument, also to be flown on AM-1. Concepts regarding the detailed operations of these IPs are being negotiated. The IP interfaces will be governed by Memoranda of Understanding negotiated by the EOS Program Office at NASA Headquarters. The ground system interfaces are covered in the project implementation plan. Detailed ground system interfaces will be specified in Interface Control Documents (ICDs) between the ESDIS Project and the respective IP Projects. Section 3.2.1 describes concepts of IP involvement in command and control, data handling, and data processing.

SECTION 3. INTEGRATED SYSTEM & MISSION OPERATIONS CONCEPTS

3.1 MISSION OPERATIONS CHARACTERISTICS

The mission operations to support EOS have several characteristics (see Figure 3.1-1) that present interesting challenges to developing and implementing concepts for the efficient and effective command and control of the multiple spacecraft and the subsequent processing, archiving, and distribution of the data.

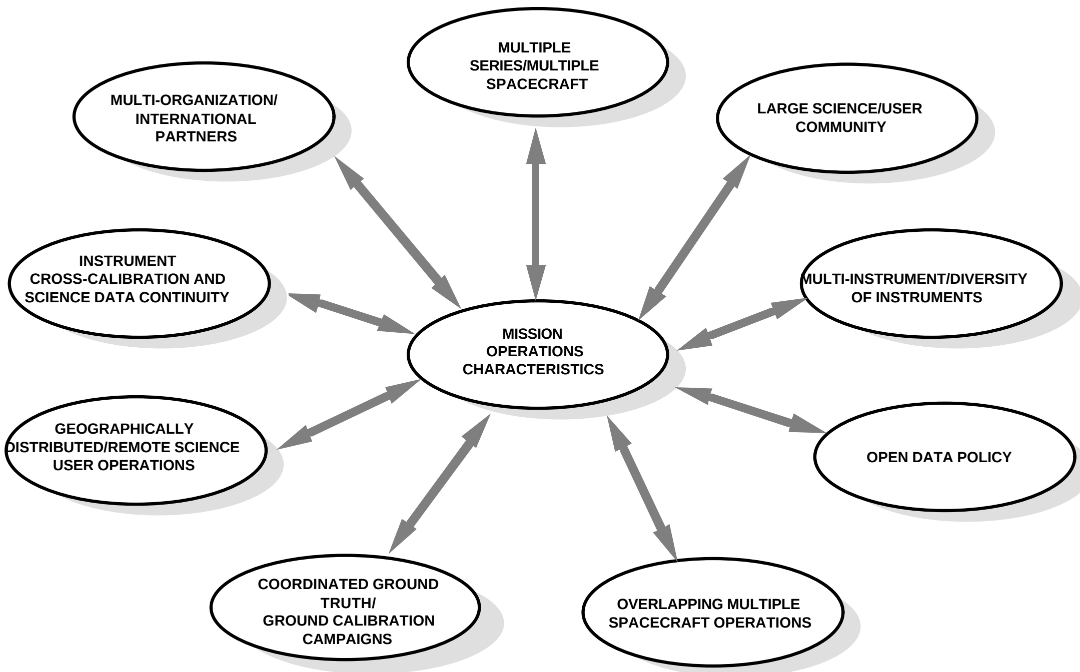


Figure 3.1-1 EOS Mission Operations Characteristics

NASA is developing a ground system to accommodate certain EOS operations characteristics:

- During the more than 20 year observation period of EOS, as many as four spacecraft (one from each series) will perform simultaneous on-orbit operations.
- An additional spacecraft from the same series will be on-orbit during a spacecraft crossover period of up to 6 months. This period enables instruments on the replacement spacecraft to perform cross-calibration with the replaced instruments and ensures scientific data continuity.
- The ground system will incorporate operations for a distributed science/user community.
- Ground truth/ground calibration campaigns will be coordinated to ensure the accuracy and validity of the instrument performance and the software used to produce data products.
- EOS operations will include participation from IPs with instruments on EOS flights.
- There will be an open data policy that makes all EOS data and products available to authorized users following processing, without preferential data rights or a period of exclusive access.

3.2 INTEGRATED SYSTEM CONCEPTS

Integrated system concepts are operations concepts requiring a total systems view (i.e., concepts that affect two or more entities among the space segment and the ground and user community segments). These concepts will be formalized as operations requirements for the relevant systems and subsystems.

3.2.1 International Participation

The international partners are complementing the U.S. spacecraft in a cooperative effort by developing Earth science instruments and polar-orbiting spacecraft to monitor global change. Science data exchanges between the International Partners Data Centers (IPDCs) and the EOSDIS will allow the user community to have greater access to multiple data sets and data products.

The current concept for international partner instrument operations on a U.S. spacecraft is for the international partner to provide an instrument control center or support terminal at the international partner's location to interface with the EOSDIS flight operations systems for command and control and the health and safety monitoring of the instrument. For science data processing of international partner instrument data, level 0 processed data sets will be provided by the EOS ground system to the international partner's ground system, either electronically or via physical media. The international partner's "DAAC" will then provide level 1 processed data and any other required input data to the EOSDIS as negotiated.

3.2.2 CCSDS Compatibility

A major concept in the end-to-end design of the spacecraft will be to provide full compatibility with the standards recommended by the Consultative Committee for Space Data Systems (CCSDS) for the uplink and downlink data flows. This concept is integral to the design of the spacecraft's' Command and Data Handling (C&DH) subsystem. Using CCSDS standards gives increased flexibility by allowing data packet sizes that vary in length, which allows instruments on the same spacecraft to use different packet sizes based on individual needs. The C&DH subsystem for each spacecraft can interleave the varying packet sizes for transmission to the ground. The use of CCSDS packets results in reduced complexity in the ground data processing system.

CCSDS command packets from the EOC will be uplinked via the EDOS and the EOS ground stations or the SN to the spacecraft and routed to the instrument. The packets can convey command information or be part of a load for an instrument microprocessor. Similarly for the downlink, an instrument will output science, housekeeping, and engineering data packets for routing within the ground segment. An instrument team may also include ancillary data within the engineering data packet to support subsequent data processing.

Another advantage to conforming to CCSDS standards for uplink and downlink is the compatibility it will provide with the international partners, who are likely to implement the CCSDS formats in their spacecraft and ground systems.

3.2.3 Concepts and Guidelines for Instrument Design

The following are concepts for instrument design that consider the ground system operations.

For many EOS instruments, switching between science modes requires repetitive command sequences. Using stored commands within the spacecraft onboard computer to perform this function would expand its memory requirements unreasonably. Therefore, instruments will be encouraged to perform repetitive sequences of commands internally in response to single "change mode" commands.

To facilitate real-time operations, engineering data will be sent in packets that are separate from the science data. For instruments for which the combined science and engineering data rate are low ($\leq$20 kbps), the science and engineering data may be combined into a single packet.

To allow flexibility and to expedite handling of the data through the ground system, the header parameters in the data packets should be settable from the ground. These parameters will be used to determine how to process the data (e.g., expedited data processing) and how to route the data from the ground terminals to EOS ground system elements such as the EOC/ICCs and the DAACs. Instrument processor dumps will be sent in their own set of packets. An alternative method, in which the memory is dumped a few bytes per engineering frame, is less desirable but is acceptable if the total instrument memory size is small.

3.2.4 Instrument Operations From the Investigator's Perspective

From the investigators' perspective, instrument activities in general will be planned and scheduled based on science plans developed by the Project Scientist and the IWG. Commands will be sent to the instrument, the observations performed, and the data processed and analyzed. EOSDIS will obtain the resources required from the space and ground segments to receive the data. Once the observations are made, EOSDIS will process the data and provide them to the investigators for analysis and research. Operations performed by the ground system will remain largely transparent from the investigators' perspective.

Figure 3.2-1 illustrates the investigators' view of the operations of their instruments. The IST will usually be located within the investigators' SCF. The science investigator or his/her instrument operations team will use an IST interfaced to the EOC to support or perform instrument planning and scheduling, to make command requests to the EOC, and to receive instrument and spacecraft data for instrument monitoring operations and anomaly investigation. The ISTs will also be used by Instrument Engineering Teams (IETs) to support instrument performance assessment and trend analysis, sustaining engineering and maintenance, anomaly resolution and other activities involving instrument performance.

For Interdisciplinary Investigators (IIs) involved in analyzing data from more than one instrument, requests for specific observations in support of their investigations, as well as requests for archived data, will be handled through an information management service provided by the DAACs. Requests that affect instrument operations will be scheduled through the normal planning and scheduling process (Section 3.6.1). Before and after spacecraft launch, the IIs will be involved in planning and scheduling instrument operations through their participation in the IWG and science planning groups.

The Project Scientist's role in instrument planning and scheduling (including conflict resolution) will be discussed in Section 3.6.1.

3.2.5 Security

The NASA EOS has been declared a national resource. Security provisions have been established for the spacecraft and the EOS ground system in accordance with policies and guidelines set forth in the GSFC Security Manual (GHB) 1600.1; the NASA Physical Security Handbook, (NHB) 1620.3B;

and NASA Management Instruction (NMI) 2410.7A (Assuring the Security and Integrity of NASA Automated Information Resources). An EOS security plan will be developed to address overall security policy, including physical, computer, communications, information, and operations security. The plan will be developed in coordination with, and approved by, the GSFC Security Office.

3.3 MULTIPLE SPACECRAFT OPERATIONS

The EOS mission is different from others in that the flight operations system and procedures must be developed to handle many variables such as simultaneous operations of multiple on-orbit spacecraft, multiple levels of instrument operational complexity, and varying rates of telemetry to be handled and processed by institutional services and the EOSDIS. Support for I&T and simulations for replacement/new spacecraft must also be planned to ensure a smooth transition before and during crossover operations.

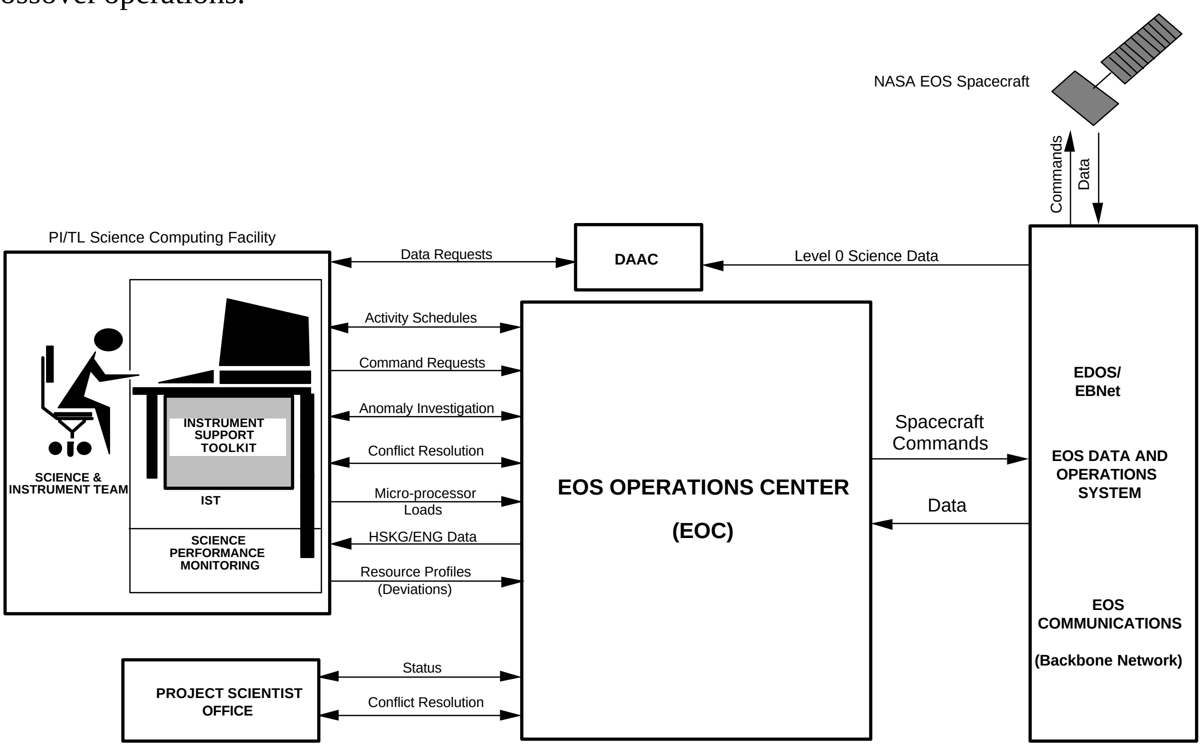


Figure 3.2-1 Operations from the Investigator's Perspective

3.3.1 EOS Operational Evolution/Flexibility

A major aspect of accomplishing the goal of maximizing science return from the EOS mission is developing and operating a ground system that continually evolves to handle EOS spacecraft on-orbit. In particular, the mission operations segment must be developed with the capability to expand and evolve to handle the varying operational loads as the mission progresses. Additionally, mission operation components must be flexible enough to accommodate the potential differences in spacecraft design and operations and to adjust to evolutionary and technological advancements in other parts of the ground system. The concepts below will be used in particular by the flight operations segment and can be found in more detail in the reference documents in Section 2. Concepts for multimission staffing will be discussed in Section 4.

Commercial Protocols and Standards:
To facilitate evolution within flight operations, commercial protocols and standards will be followed and commercial off-the-shelf products will be used when it is technically and economically feasible. By following commercial standards and protocols, the system may expand and evolve without relying on or being tied to a specific vendor.

Operations Automation:
Advances in ground system hardware and software allow developers to evaluate potential areas of automation. Three key factors must be judged and balanced when deciding upon an automated approach. First, will automation of a particular function increase overall productivity, either by increasing quality or by decreasing the amount of time needed to produce the product? Second, will automation reduce the operational risk of a function by eliminating the "human factor" in the process? Great care must be taken when evaluating this factor in order to ensure that human "sanity checks" and common sense aren't needed to perform these tasks. Third, will the use of automation provide a benefit to the overall life-cycle costs of the system? The priority of this third area continues to rise within the current budget-constrained and cost-driven environment.

A prime example of automation within mission operations is the use of decision support systems for use in both real-time operations and non-real-time spacecraft analysis. These systems, either rule-based or logic-based, are used to monitor telemetry, analyze spacecraft status, and project potential spacecraft status. These systems are also used to detect anomalies and provide resolutions, evaluate and project onboard spacecraft resource usage, and perform “what if” analysis on operator inputs. These systems can also be valuable tools for gathering operator and subsystem expertise that might otherwise be lost through the mission life. Such a system, however, must be developed so that it is relatively easy to operate, highly reliable, able to output information in a timely manner, and easily inserted into the architectural framework of the ground system.

Operations Architecture - Efficiency and Performance:
Mission operations must be designed to support multiple spacecraft in varying states of development, testing, and operations simultaneously and to support operations in an efficient, streamlined manner. The challenge in fulfilling this requirement is that the system will evolve over a period of years before the full complement of spacecraft are designed. Thus, a robust architectural framework is needed to support this system. A modular design will be used to enable technological advancements to be inserted, while improving system maintainability.

The flight operations architecture, and in particular the EOC, will be designed to maximize commonality and achieve minimal maintenance and life-cycle costs, increase overall operations efficiency, and allow the FOS to expand and evolve as the EOS era progresses. The EOC is being developed to operate in a workstation environment. Each workstation will have the capability to perform all operational functions (i.e., command and control, health and safety monitoring and data management), permitting the operators to tailor each workstation to the spacecraft or multiple spacecraft that they support. Performing these functions on powerful desktop workstations distributes system loading and ensures that users will not interfere with one another. Operations requiring large amounts of processing power can be performed on specialized server machines without interfering with time-critical operations. The user can initiate the operation from a workstation; however, the fact that the task is being performed on another computer in the network is transparent to the user. Adding users to the system (e.g., for launch) will not necessitate the upgrading of other components. Workstations supporting real-time operations will be isolated from support workstations by separate networks. The capability to switch networks will be provided under controlled conditions. The flexibility inherent in this architecture will allow workstations to be added, deleted, or rearranged to increase efficiency within the EOC without affecting the system architecture or performance.

Another key component in the design of the flight operations ground system is the use of logical strings. Using the internal flight operations network, a logical string connects the command and telemetry functions of a single spacecraft to support real-time contacts or other specific processes (e.g., housekeeping playback analysis or simulations). Many users can connect to a logical string to monitor or participate in flight operations. The logical string concept enables the operations personnel to support multiple spacecraft and instruments more efficiently, since a workstation can connect to more than one logical string at a time. It should be noted that this concept does not apply to command operations, in which only one authorized user will have command authority over each spacecraft.

Object-Oriented Use:
An object-oriented methodology will be used for software development within the ground system. Object oriented methodology emphasizes encapsulation and inheritance. Encapsulation provides the capability to change functionality that is implemented in classes without disturbing the design or implementation of other classes. For example, a required change to a microprocessor load would be isolated in that class and would not propagate to other aspects of the system. The inheritance feature of the FOS design provides a powerful tool to accommodate the extension of an FOS capability without duplicating the design, implementation, and testing accomplished for a similar capability. The design of an inheritance hierarchy allows the specialization of an existing class, including additional or modified functionality, while retaining the full capabilities of the parent class and not disturbing its integrity.

Graphical User Interfaces and a User Friendly Operations Environment:
Although automation provides a great benefit to the operations environment, the health and safety of EOS spacecraft is still the responsibility of the operations personnel within each of the flight operations elements. Real-time commanding, health and safety monitoring, ground system configuration and resource usage are performed daily by human operators. The amount of information to monitor, analyze, and track is significant and can be made even more difficult under conditions that require prompt response and place the operators under extreme pressure. Past control centers added to the burden by providing the operators with environments that included text-only displays, cramped working spaces, and generally unpleasant working environments for the responsibilities they were given. The EOS mission operations environment must ensure that information is presented to the user in the most efficient and user friendly manner possible. Operations analysis tools and expert systems provide limited benefits if they are so difficult to operate that the operations personnel avoid using them and go back to the "old fashioned" methods. Operations displays will be designed to allow users to tailor their workstations as desired. Graphical User Interfaces (GUIs) should be provided where they most benefit the user (e.g., in monitoring real-time telemetry and displaying limit violations). Again, care must be taken to avoid overburdening the operators with too many "bells and whistles" that not only cost more, but slow down rather than speed up certain processes. In addition, use of GUIs must also be factored against overall system performance to ensure that a workstation isn't spending a large amount of processing power on the displaying of information

rather than the processing of information. Finally, the operations areas must be ergonomically designed to provide a work environment that allows operations personnel to focus on their tasks.

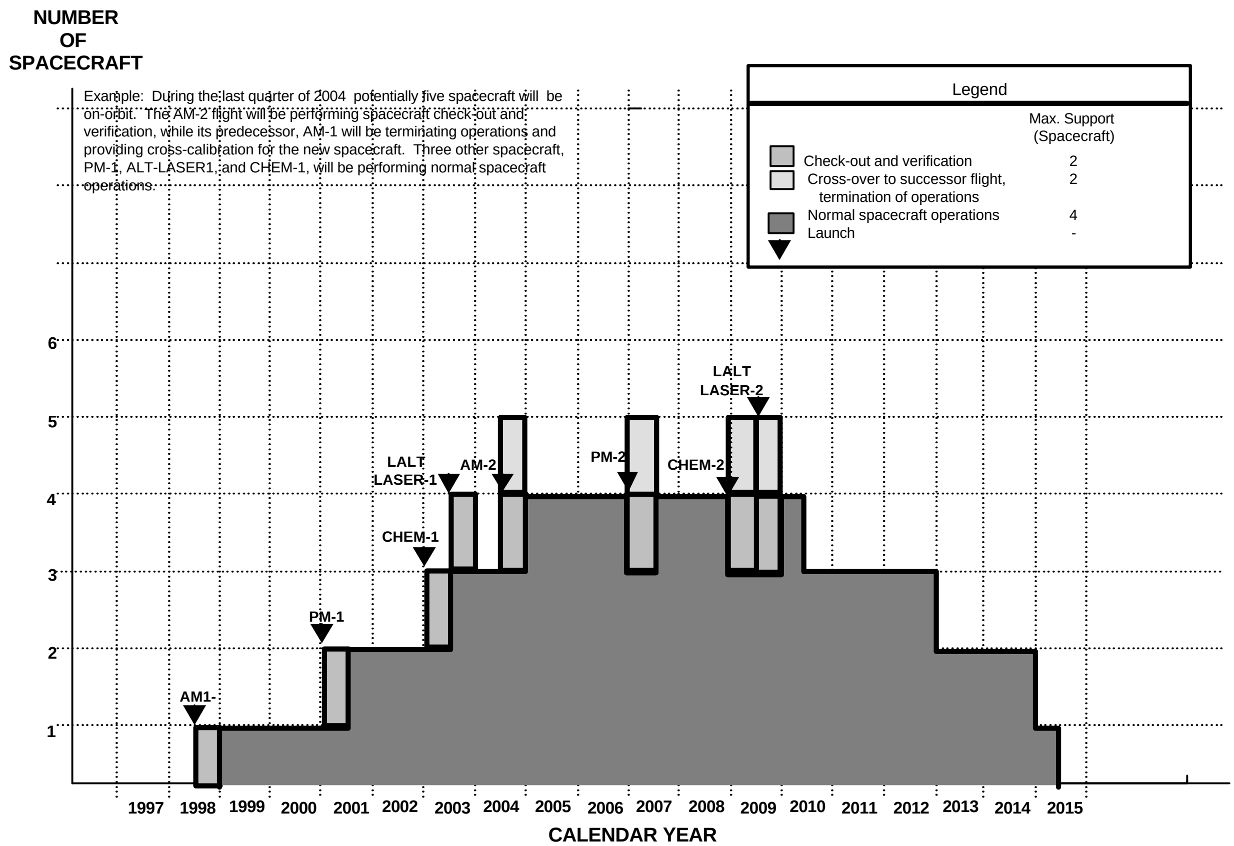
3.3.2 EOS Operational Loading

Figure 3.3-1 shows an estimate of the EOS operational load. As shown, as many as four spacecraft (year 2003) will be performing normal on-orbit operations simultaneously. During periods (up to 6 months) of crossover operations, up to five spacecraft will be on-orbit, all requiring planning and scheduling, command and control, and monitoring for health and safety and spacecraft performance. In addition, prelaunch operations (e.g., I&T, simulations, ground system compatibility tests, and operational readiness tests) for successor spacecraft must also be supported.

Analyzing each instrument's operational complexity will aid in determining the loads expected on the EOC, the ICCs (if any), and the ISTs. "Non-complex" instruments (in terms of the ground interaction required) have routine or autonomous operations requiring minimal ground interaction. The "complex" instruments are those instruments capable of non-contiguous data acquisition with variable pointing. Hence they require daily planning, scheduling and commanding. Table 3.3-1 categorizes the EOS instruments' operational complexity.

The real-time health and safety monitoring for non-complex instruments will be handled within the EOC. Other functions, such as planning and scheduling, will also be handled within the EOC and supported by the instrument team through an IST. Instruments requiring a dedicated 24 hours-a-day staff to perform functions such as planning and scheduling, command load generation, and instrument health and safety monitoring will be operated by their respective ICCs.

To determine the potential physical and personnel resources required to support multiple spacecraft operations, an in-depth analysis will be performed to determine the average and peak support requirements for normal and contingency operations. This analysis will consider priorities for scheduling mission support for the various spacecraft, the additional resources required during contingency operations, and the requirements for reliability and maintainability of the ground system. The ground system will be "optimized" where feasible to provide the necessary capabilities.



[Based on Launch Schedule from MTPE/EOS Reference Handbook dated 1995]

Figure 3.3-1 EOS Mission Operational Load

3.3.3 Coordinated Scheduling of EOS Ground System Resources

It is essential that the major segments of the ground system (e.g., *flight operations*, *science data processing and distribution*, and *communications and system management*) support spacecraft operations in a coordinated manner. Proper coordination will be needed within the EOSDIS and between the EOSDIS, NASA institutional elements (i.e., FDD or NCC), and any external systems involved in mission operations. Figure 3.3-2 summarizes the expected average telemetry rates for EOS. The vast amounts of data that will be received, processed, archived, and distributed require proper scheduling within each of the major segments to ensure that all systems work smoothly and efficiently. This is particularly important during spacecraft crossover periods, where the amount of data to be processed will double during portions of the crossover when both spacecraft are fully operational. An increased emphasis will be placed on proper scheduling of the direct playback contacts and/or TDRSS during spacecraft crossover operations periods to avoid overburdening EDOS.

The integrated planning and scheduling of flight operations will be the responsibility of the EOC. The EOC will coordinate these activities with the ICCs, the ISTs and the NCC. The EOC will work internally to coordinate contacts for EOS ground station support and will negotiate with the NCC for the use of TDRSS resources as needed. Planning and scheduling for multiple spacecraft operations and the corresponding requests for TDRSS services through the NCC must be properly coordinated. Proper coordination between the EOC and the NCC for TDRSS services and within the EOC for

EOS ground station services will minimize interference among spacecraft and decrease the impact of contingencies resulting from any other mission emergencies (e.g., a Space Transportation System (STS) emergency, which could change priorities for single access communications availability). Increased flexibility for TDRSS support may be obtained by providing each spacecraft with the capability to communicate with any of the four TDRS spacecraft. This approach allows greater flexibility for supporting the multiple spacecraft operations while conforming to standard NCC scheduling procedures.

The coordination and scheduling of activities required to perform science data processing will be provided by the SMC, which is the focal point for system-wide element management of ground operations for the EOSDIS.

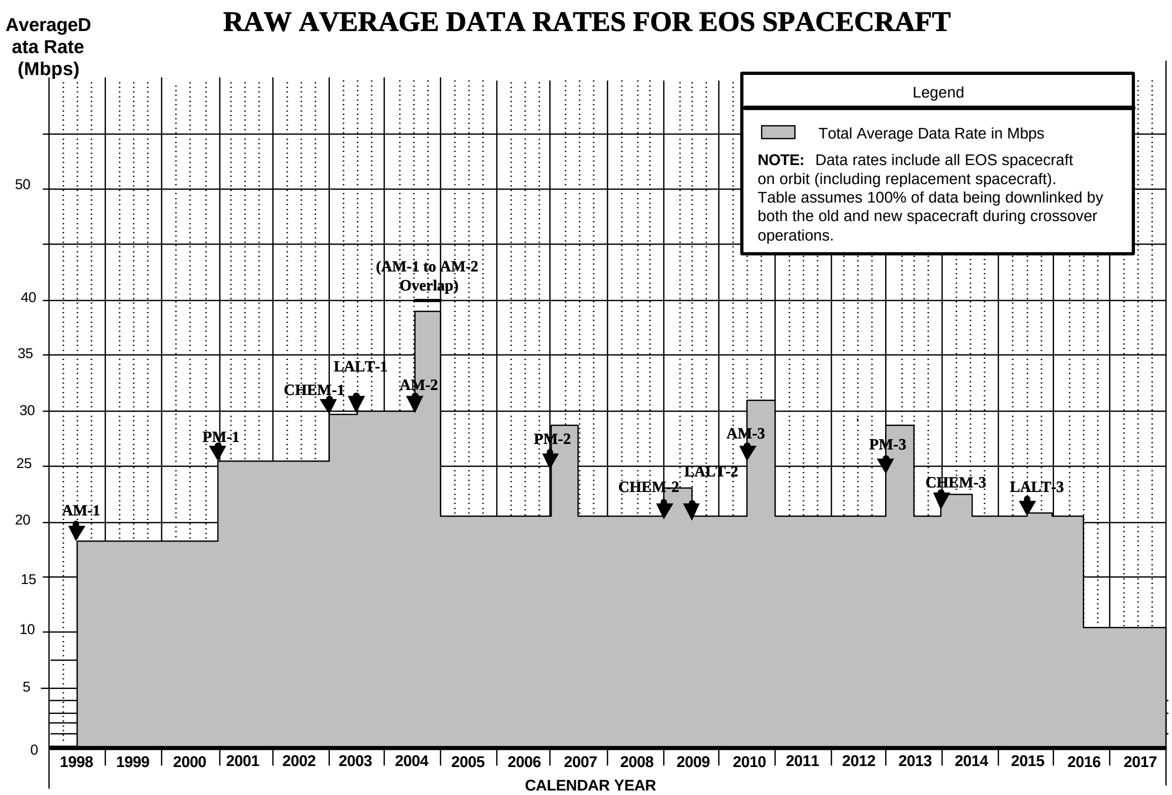


Figure 3.3-2 EOS Composite Telemetry Rates (Based On Planned Spacecraft)

Table 3.3-1 Operational Complexity Of EOS Instruments

Noncomplex		Complex
AIRS AMSU CERES EOSP MHS AMSR MLS MODIS MOPITT ODUS LATI	GLAS HIRDLS MISR	ASTER (external ICC) TES (TBD)
• Constant duty cycles • Automatic or simple calibration • Very little ground interaction required	• Need for infrequent operations changes due to change in science goals or target-of-opportunity	• Targetting instruments

3.4 CONCEPTS FOR PRELAUNCH READINESS

Prelaunch readiness concepts define the preparation of the space and ground segments to ensure that total mission capabilities and objectives can be met.

3.4.1 Early Mission Operations Concept Development

Early consideration of mission operations concepts and the envisioned mission environment is necessary for any space program. It is especially important for a long-term program that includes multiple spacecraft operations and a complex distributed ground system. The EOS MOM, in cooperation with each of the flight project OMs, the EOSDIS flight operations personnel, and the various operations working groups, is responsible for developing the concepts for EOS mission operations. These concepts consider not just the first EOS spacecraft, but all aspects of the multiple spacecraft mission, and is used to influence the design, development, and testing of the needed capabilities.

3.4.2 Mission Operations Plan and Operations Procedures Generation

Mission Operations Plan:
The EOS Mission Operations Plan (MOP) will provide the concept of how the mission operations for each EOS spacecraft will be conducted. The information will include mission phases, mission operations, data management, operations support, configuration control, and training. The mission operations plan will also provide generic operations procedures, such as how to perform real-time commanding.

Flight Operations Plan:
To provide more detailed information on each flight, a Flight Operations Plan (FOP) [or a similar document] for each spacecraft will be developed using the MOP for guidance. The FOP will use common information for each spacecraft within a series and may be developed as a master plan with add-on appendices for each spacecraft. The FOP will provide detailed activity timelines and spacecraft operational descriptions for each phase of the flight. The plan will outline contingency

initiatives and spacecraft safe-hold operations. The operations support section of the plan will include EOC organization, staffing and support, science investigator support, and other EOS ground operations support.

Operations Procedures:
Operations procedures will be defined for performing routine and contingency operations during end-to-end testing and the various mission phases. Flight operations procedures will be generated using the EOS spacecraft operations and maintenance (O&M) manuals provided by the spacecraft contractor. The FOT will take the information contained in the O&M manuals and develop operations procedures, operations scripts, contingency procedures, and automated EOC procedures to support spacecraft operations. These procedures and scripts are verified during training and simulations and are updated as needed during the flights for FOT use.

3.4.3 Spacecraft Integration and Test

Integration and Test (I&T) of the instruments will be conducted at the instrument developer site. I&T of the spacecraft assembly and test with the instrument complement will be conducted at the spacecraft contractor's facility.

I&T of the spacecraft is conducted at the spacecraft contractor's facility before delivery and assembly of the tested instruments. Testing on the spacecraft is performed at three levels: component, subsystem, and spacecraft. Upon assembly and test of the instrument complement, testing of the integrated spacecraft with the ground system and the space-to-ground links is performed to ensure compatibility before the integrated spacecraft is shipped to the launch site. If available, the Compatibility Test Van (CTV) will be used at the spacecraft contractor's facility to characterize the spacecraft's Radio Frequency (RF) and ensure compatibility between the spacecraft, the TDRSS and the GN respectively. The capability to conduct I&T at the developer's site allows system level verification before spacecraft shipment. The flight project I&T manager will coordinate between the spacecraft contractor and the ground system elements in order to ensure that time-constrained spacecraft I&T activities are not disrupted, and that all involved parties understand the objectives of each test.

To further aid the process of I&T for an integrated spacecraft (instruments and subsystems), each instrument developer will be encouraged to use common systems test and operations language software for instrument I&T. Thus instrument testing on the spacecraft can begin much sooner because the spacecraft contractor does not have to extensively modify and translate each instrument's test procedures into the language that the spacecraft recognizes.

3.4.4 Ground System Testing, Verification and Readiness

Testing of the EOS ground segment must take into account two of its major characteristics. First, the size and complexity of the ground system dictates that a time-phased buildup should be performed. The ESDIS I&T manager will coordinate the phased buildup of the EOS ground system in a logical sequence. An I&T plan will provide for testing and acceptance of the various elements in an efficient and effective manner, which is especially important because of the number of separate government and contractor organizations involved. Second, the EOS ground system will continually evolve over the mission lifetime. As subsequent versions or "releases" are incorporated into the EOS ground system, an I&T plan will be generated to verify the functionality of the new ground system version. Another important consideration is to make sure that testing and acceptance will be performed with little or no impact on day-to-day operations.

EOS ground system testing will follow the formal integration test and verification process according to the EGS I&T Plan. Some testing support will be provided by the MO&DSD to the EOS project, as determined by the ESDIS I&T Manager.

Testing of the overall EOS ground system will occur in several stages as the various elements are implemented. Individual ground system elements will be implemented in phases (i.e., versions or "builds") because of their size and complexity. The development contractors will perform initial testing of their respective ground system elements. Testing will then proceed to functional and interface testing among the ground system elements and will continue through compatibility testing, end-to-end testing, acceptance testing, and operational readiness testing.

To facilitate the development of the EOS ground system, test data created at the spacecraft contractor's facility and each instrument's development facility must be provided early to test the functionality of each EOS element and the compatibility among elements of the EOS ground system. Testing of the mission-critical elements of the ground system (i.e., the SN, EDOS, EBnet, EOC, ICCs, and ISTs) may be accomplished using real-time data flows. Testing of the data processing elements will include the use of recorded instrument data to verify the science algorithms used in standard data production.

Functional and Interface Testing:
Functional and interface testing will be performed in several steps. The development contractor will conduct functional and interface testing to verify that the integrated system meets the design specifications. A validation test will then be conducted to determine if the hardware and software meet the system requirements specifications. A subset of the validation test, witnessed by NASA personnel, will constitute the basis for a formal system test. The formal system test will provide NASA with a contract milestone but will not relieve the development contractor of the responsibility for correcting problems identified in later tests.

RF Compatibility Testing:
RF compatibility testing will demonstrate the compatibility of the spacecraft with SN and GN resources and the EOC. Tests on the forward and return links and the spacecraft RF signals will be conducted to ensure proper operational interfaces. The CTV or a rooftop antenna will be used to provide connectivity between the spacecraft and the SN/TDRSS. X-band compatibility testing with the EOSDIS ground stations is TBD.

EOS Compatibility Testing for AM-1:
Verifying the compatibility of the AM-1 spacecraft with the EOS ground system, and in particular the EOC, will largely be accomplished incrementally through EOC Compatibility Tests (ECTs). Three ECTs will be performed for the AM-1 spacecraft during the integration and test phases, with the first of these (ECT1) planned approximately 16 to 18 months before launch and the last (ECT3) planned 5 to 6 months before launch. ECT1 will demonstrate the capability of the EOC to generate commands, validate the Project Database (PDB), and process the housekeeping telemetry from the spacecraft. The EOC will link with the spacecraft using an EDOS simulator to perform the necessary EDOS functions for command and control. ECT2 will provide comprehensive verification of the EOS command and telemetry functions. The SN and EDOS will participate in the test, which will exercise all command and telemetry rates, including solid state recorder dumps and spacecraft

memory loads/dumps. The primary objective of ECT3 will be to demonstrate the science data flow to the DAACs and to the interfaces with the instrument teams via the ASTER ICC and the ISTs. The final verification of system compatibly will be accomplished through end-to-end testing.

End-to-End Testing:
The spacecraft projects and ESDIS will work cooperatively with ESDIS to develop and conduct end-to-end testing. End-to-end testing will be conducted to demonstrate the functionality of the entire EOS operational data system, from the science instruments and spacecraft subsystems through the SN and/or ground stations, EOSDIS, and the users. The end-to-end tests will exercise the full range of spacecraft and ground system capabilities to determine the adequacy of the mission-critical elements and the effectiveness of operations plans and procedures. End-to-end testing of the mission-critical elements will require operational time with the spacecraft at the spacecraft contractor's facility and, as applicable, at the launch site. The CTV or a comparable service will be required to access the SN. The spacecraft assembly and test schedule should accommodate this testing. Science data that is recorded during this period will be used for testing of the data processing elements. A subset of the data from the end-to-end tests is usually delivered to selected users for verification. These data will be part of the characterization data sets for some instruments.

Verification and Validation Testing:
An independent test organization will perform verification and validation to ensure overall system compatibility, acceptance, and readiness. The Independent Verification and Validation (IV&V) Manager from the ESDIS Project is responsible for V&V activities. The IV&V team will track ground system design, specifications, and implementation and will monitor all EOS ground system integration testing. The IV&V team may develop additional tools for testing possible trouble spots within the ground system. This team will determine whether the developed system meets all applicable requirements.

Operational Readiness Testing:
Ground system readiness to support the mission will be established during and after verification and validation testing. When the I&T manager is satisfied that the ground system requirements have been met, he/she will formally deliver the ground system to the MOM. It is the responsibility of the MOM to demonstrate the operational readiness of the mission-critical elements and the FOT. Demonstrating operational readiness requires demonstrating the readiness of the entire operations staff as well as all operations plans and procedures. Data flows and simulations are usually conducted before launch to achieve and maintain a high level of operational readiness. The test status and successful completion of operational readiness testing will be presented by the MOM or the FOD at the Operations Readiness Review (ORR).

3.4.5 Training and Simulations

The concept of training and simulations is driven by several significant factors. The EOS space and ground segments are large and complex. Over its lifetime of at least 20 years, EOS total operations costs will represent a sizable portion of the total program cost. Potential operational errors can be costly in terms of system failures and degradation, and ultimately in terms of lost data and services. Also, significant personnel turnover can be expected over the lifetime of EOS. Therefore, it is important that all operations personnel be properly selected and thoroughly trained throughout the EOS mission. These factors lead to the need for initial training; recurrent training; and cross-training of personnel, which also supports multiple spacecraft operations as discussed in Section 3.3. These factors also require the availability of effective spacecraft simulators, which are indispensable tools for achieving a high level of operator competence and enables the ground system, flight operations plans and procedures, and flight software to be thoroughly tested and validated. The EOS spacecraft projects are responsible for developing a spacecraft operations training plan and associated material

The EOS approach to training will provide for the training of the FOT to support prelaunch ground testing, launch, and flight operations of the EOS spacecraft. The individual EOS Projects have the responsibility to train the Flight Operations Team (FOT) in the operation of the spacecraft and associated simulators. Training will be conducted to maintain the operational knowledge of the FOT throughout the life of the spacecraft and in certain cases to cross-train operations personnel in one or more functional positions (e.g., operating the same position for multiple spacecraft). Operations personnel who are candidates for the training program will be properly screened in accordance with a set of established criteria (e.g., aptitude, experience, and education) to ensure that they meet appropriate qualifications before being admitted to the training program. ESDIS is responsible for an ECS training plan and associated material.

The training and certification will be performed in accordance with a plan developed by the FOT and reviewed and approved by the MOM and the spacecraft FOD. Training will consist of three distinct types: initial training, recurrent training, and cross-training. Training before launch will be structured differently from that during on-orbit operations. The training program will accommodate the phased arrival of personnel in small groups throughout a period of 1 to 2 years before launch. Training will address both normal and contingency operations. Following spacecraft check-out and verification, training will be oriented to training new staff, who arrive individually; to maintaining and improving the operational knowledge of current staff; and to providing staff on new spacecraft.

The EOS operations training program will consist of several activities. Classroom training will be conducted in accordance with an approved syllabus and will cover flight and ground system design, performance and functional capabilities, operations plans and procedures, and general system operations knowledge and theory. Training will also require self-study, on-the-job training (OJT), and use of the spacecraft simulator. To manage the training and certification program, a flight operations training director will be selected and a staff of training instructors will be organized for specialized areas. Training tools and materials such as instruction manuals, lesson plans, self-study reading guides, exercise and simulation scripts, videos, and training records will be prepared.

A system for measuring and evaluating training progress and the status of the operations personnel will be established. Certification of a core of flight-ready operations personnel will be completed by launch minus 3 months. Certification of new personnel will be performed throughout the life of the mission as turn-over of flight operations teams occurs. Recertification of existing personnel will also be done during various stages of the mission to insert new technology or to maintain a high level of operator proficiency.

3.5 CONCEPTS FOR LAUNCH, CHECK-OUT, AND VERIFICATION

The spacecraft contractor(s) will provide subsystem engineering and instrument personnel, as required, from pre-launch through launch and spacecraft/instrument activation and check-out time frames. During the launch, check-out, and early orbit verification periods, the spacecraft may be more susceptible to anomalies than during other periods of flight operations. This period provides knowledge regarding the actual operations performance of a particular spacecraft/instruments to the spacecraft and instrument operations teams. At spacecraft separation, primary operations responsibility will be transferred from the launch site operations facility to the EOC. An integral concept for ensuring proper spacecraft activation, check-out, and verification will be the development of planned and validated flight operations procedures. These procedures will be developed through a coordinated effort by the operations and engineering teams and will be extensively tested and evaluated with the spacecraft and instruments during spacecraft integration when feasible and with simulators when the availability of the actual hardware is limited. A separate set of contingency procedures will address contingency scenarios and the corrective actions to be taken. Procedures for normal operations and selected contingencies will be formally validated by test.

An integral part of the last portion of instrument verification for replacement spacecraft is the use of the old spacecraft for cross-calibration. This cross-calibration satisfies the requirement for data continuity between old and new instruments throughout the EOS mission.

3.5.1 Spacecraft Verification and Calibration (Post-Launch)

Spacecraft subsystems will be exercised and their performance assessed to verify that they meet specifications. During this period, the scientific instruments will be left in their launch state or put into a safe state. The EOC will verify each subsystem, using validated subsystem performance assessment plans and procedures. Critical subsystems, such as communications and attitude control, will be verified first to ensure that ground communications and attitude control are maintained throughout the remainder of the verification period. The spacecraft contractor(s) will provide assistance to the FOT during launch as well as post-launch time frames.

Upon completion of the subsystem performance assessment, all scientific instruments will be verified. The instrument teams will verify the engineering integrity of the instruments and then perform an initial assessment of the housekeeping and engineering data to ensure that the instruments are operating within specified limits. The EOC, ICCs, and ISTs will verify and monitor each instrument, using validated instrument performance assessment plans and procedures. Instrument personnel may elect to be physically located at the EOC during this period. Arrangements with each instrument will be negotiated premission. In conjunction with the initial instrument verification, the EOC will begin calibrating the spacecraft subsystems, again using validated procedures, to ensure that any pointing errors are minimized. If any misalignments exist, table loads will be generated, validated, and uplinked to the spacecraft to take into account these misalignments.

After proper spacecraft alignment has been validated, each PI/TL team will calibrate its instrument if necessary (via the EOC, ICC, or IST) using validated procedures. For successor spacecraft in a series, the instrument operations team for a new spacecraft will coordinate with the instrument operations team on the replaced spacecraft to perform instrument cross-calibration. Spacecraft on-orbit check-out and verification may last 3 to 6 months.

3.5.2 Orbit Determination and Maintenance

For EOS AM1, orbit determination will be performed onboard using the TONS and supported on the ground by the FDD. EOS PM1 will use orbit determination solutions prepared daily by the FDD from tracking data. For all other spacecraft, the method for orbit determination is still undefined.. FDD support varies during the phases of each mission.

During the prelaunch phase, FDD will provide premission orbit and attitude analysis and will support ground system testing and end-to-end testing with the spacecraft at the spacecraft contractor’s site and at the launch site. During the launch phase, orbit information will be supplied by the launch vehicle contractor and will be passed by the EOC to the FDD. During the spacecraft initialization and check-out phase, FDD will provide definitive and predictive ephemerides and state vectors to the EOC for uplink to the spacecraft. After the initialization and check-out phase of the AM-1 spacecraft, TONS information will be routinely supplied onboard to an attitude and orbit control subsystem and to the instruments by the spacecraft onboard computer. The TONS data, along with other ancillary data, are downlinked with the science stream and processed, distributed and archived as part of the level 0 data sets. For other EOS spacecraft, orbit data (based on the FDD supplied orbital predicts) and other ancillary data are downlinked with the science stream and are also processed, distributed and archived.

The FDD will also provide orbit analysis, orbit maneuver planning support, transmitter oscillator frequency support and predicted orbit support. Independent tracking of the spacecraft through current TDRSS tracking services will also be performed by FDD during the initialization phase and as backup support for TONS.

The FDD and the EOC will be prepared to respond in the event of a non-nominal orbit insertion. If this occurs, an immediate assessment will be made regarding the level of criticality and whether a rapid response is required by the FDD and EOC. Figure 3.5-1 summarizes the anticipated FDD support during prelaunch, launch, check-out, verification, and normal operations. This interface will be further defined in an ECS-to-FDD interface control document.

3.6 CONCEPTS FOR NORMAL OPERATIONS

Normal operations cover a wide range of activities, from the planning and scheduling of instrument observations through command and control of the spacecraft and instruments, to the various functions needed for processing, distributing, and archiving the level 0 data, to monitoring spacecraft and instrument health and safety and performing trend analysis. Table 3.6-1 provides a summary of the various high-level concepts regarding normal mission operations of the EOS spacecraft.

These concepts are based on the assumption that most EOS observations will be planned and scheduled in advance and that command loads will be generated using these schedules for uplink to the spacecraft for delayed execution. It is planned to uplink loads once or twice per day. Execution of these stored commands may be based on absolute time, relative time, and event times. Real-time commanding will be used primarily for initial activation and check-out, contingency operations and high rate recorder dumps.

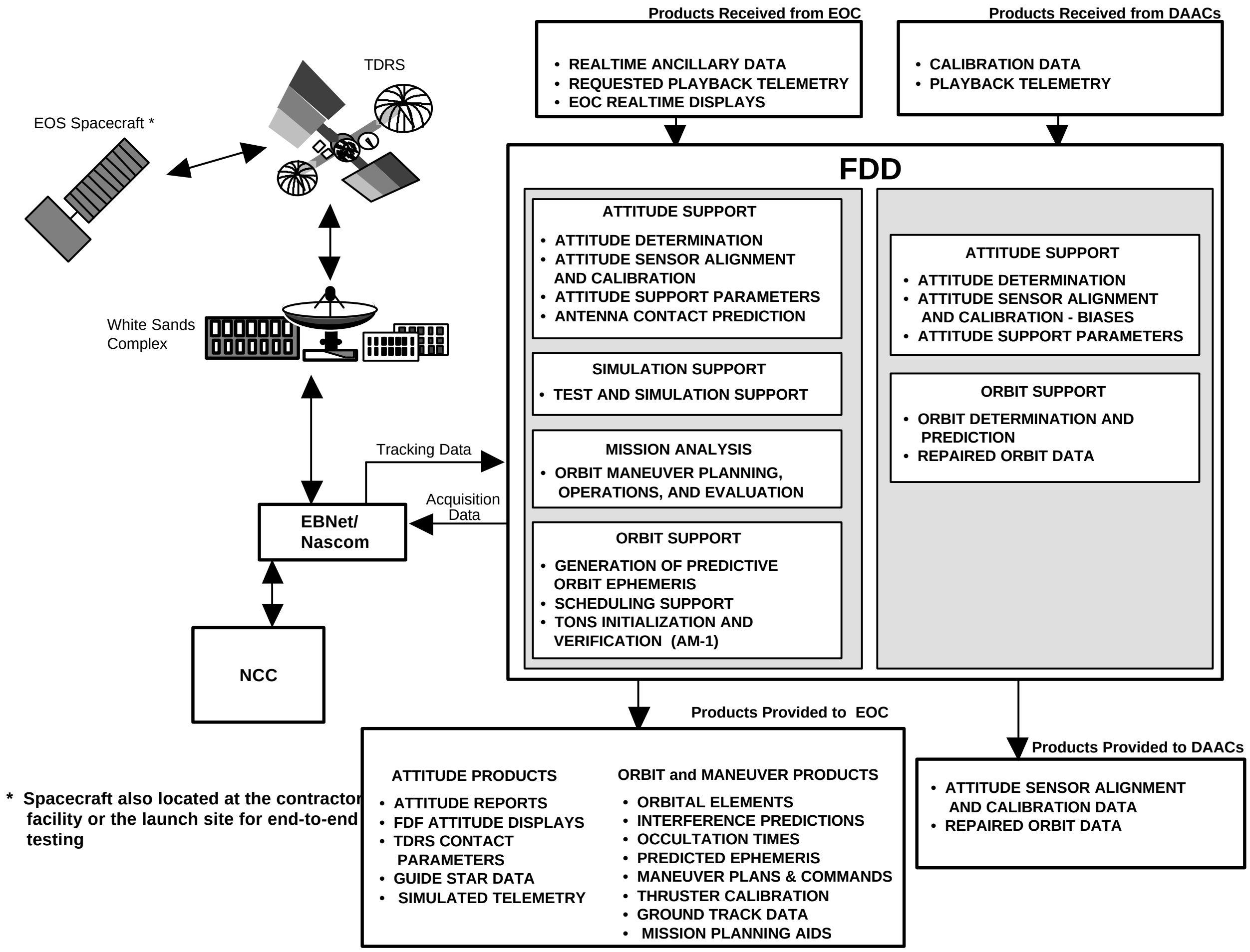


Figure 3.5-1 FDD Support Overview

3.6.1 Planning and Scheduling

Figure 3.6-1 provides a high-level timeline of the planning and scheduling process for generating a command load for a target day.

Table 3.6-1 Concepts For Normal Operations

Operations Concept	Description
Phased Planning and Scheduling	• Long term plan is provided by the Project Scientist/IWG to the ESDIS Project. • Short term planning as required. • Initial and final scheduling.
Coordinated Spacecraft Planning and Scheduling	• EOC coordinates planning and scheduling for both subsystems and instruments. • Science and instrument operations planning distributed for complex instruments; spacecraft subsystem and noncomplex instrument operations planning and overall flight timeline coordination performed at EOC. • Common planning and scheduling tools and aids for subsystems and instruments. • Reduced iterations required to prepare plans and schedules.
Geographically Dispersed Operations Facilities	• Remote ICCs for operationally complex instruments such as ASTER • EOC are accessed by remote users via ISTs. • ISTs normally (but not always) located at SCFs.
Data Packetized with Various Types Identified by Header Information (e.g., APID)	• Spacecraft data packetized and compatible with CCSDS standards. • Different packets for spacecraft H/K, instrument engineering, science, and ancillary data. • Facilitates data distribution by enabling packet switching and networking techniques.
Spacecraft Commanding	• All commands are uplinked through the EOC. • Commands sent in realtime or as a stored command load [utilizing Absolute Time Command (ATC) or Relative Time Sequence (RTS)].
Instrument Commanding	• Instrument teams send command requests/provide a command database to the EOC. • EOC stores instrument commands for noncomplex instruments as negotiated. • Instrument Teams provide updates to instrument commands stored in the EOC and provide instrument microprocessor loads.
EDOS Realtime Services	• EDOS routes realtime housekeeping packets to the EOC • EDOS provides the CLCW to the EOC as part of COP process • EDOS provides the EOC with data quality statistics in the form of CODAs
Housekeeping Data Available for Spacecraft and Instrument Health and Safety Monitoring and Analysis	• EOC monitors instrument health and safety. • EOC monitors subsystem H/K and instrument H/K to instrument teams. • PI and TL science team access housekeeping data and spacecraft status via ISTs.
Instrument Engineering Data Available for Instrument Performance Monitoring	IST responsible for scientific performance of the instrument. Instrument team can request engineering data from EOC via ISTs.
Coordination of System Status, Accounting/ Accountability, and Other Services	SMC is focal point for system-wide monitoring and coordination of EOSDIS ground operations.

EOS Project Scientist's Role in Planning and Scheduling:
The EOS Project Scientist will be primarily responsible for the planning of the EOS mission. The Project Scientist and the Program Scientist work with the IWG and the science planning groups to develop a long-term science plan that establishes science priorities and objectives for each EOS flight.

The Project Scientist will also participate in the development of long-term instrument plans, particularly for complex instruments. Prior to spacecraft launch, a target list for complex instruments will be developed by the Project Scientists, the IWG, and the instrument science team. Changes to this list may be made using Data Acquisition Requests (DARs). A user submitted DAR will be accepted for scheduling on the basis of the priorities that are preassigned by the Project Scientist. It is possible for the unaffiliated user, who has not been assigned a priority by the Project Scientist, to be allowed to submit DARs at a low priority.

The DARs will be sent to the appropriate ICC, which will accept them or deny them based on the guidelines and priorities defined by the Project Scientist. Accepted DARs will be added to the target list. The DAR acceptance criteria and priorities will be based on a number of factors, including the affiliation of the requester (i.e., IIs versus a graduate student) and the type of science that is being requested. Periodically, the Project Scientist/instrument team may go through the target list and remove DARs that no longer meet the evolving science goals or are of such low priority that their probability of being scheduled is too low. The same procedures are followed for Targets of Opportunity (TOOs). A TOO that is within the current guidelines and resources will be accepted. A TOO that creates science conflicts, but for which there are guidelines in place to resolve the conflict, may not require the involvement of the Project Scientist. A TOO that creates science conflicts that cannot be resolved by the guidelines must be approved by the EOS Project Scientist.

The EOS Project Scientist or his designee (e.g. the ESDIS Project Scientist) will normally not be involved in the routine day-to-day scheduling of the instruments or the resolving of routine schedule conflicts. The normal day-to-day scheduling will be a matter of balancing spacecraft and ground system resources and will not require the Project Scientist's involvement. Routine scheduling conflicts will be resolved by following pre-established guidelines. The Project Scientist will only be involved in resolving scheduling conflicts that have not been resolved using the pre-established guidelines.

Long-term Planning:
Long-term planning will be initiated by the EOS Program and Project Scientist, the IWG and the science planning groups from 6 months to 5 years before the actual instrument activities take place. A long-term science plan will be developed and provided to the ESDIS project. The plan will establish science priorities and objectives for each EOS flight. The plan may define periods of coordinated activities with other EOS spacecraft, with other Earth science missions, and with selected ground campaigns.

The long-term science plan will be disseminated by the SMC and made available through the EOSDIS information management service to PIs/TLs in planning their instrument operations. The science community may also have access to the plan for use in defining DARs for needed observations on complex instruments, for coordinating correlative measurements, or for planning future science campaigns.

Using the long-term science plan for guidance, the PIs/TLs will develop a long-term instrument plan. The contents of the long-term instrument plan may be fairly straightforward for simple instruments. The plan will define periods of instrument activities; periods in which spacecraft maintenance activities should be avoided, if possible; and periods of coordinated activities or special calibration activities, if required. The long-term instrument plan for complex instruments will be substantially more in depth. It will describe the guidelines and priorities for scheduling based on received DARs, TOOs, and calibration or maintenance activities. The plan will also provide more detailed information about periods of coordinated activities, specific targets and coverage requirements, science objectives for the upcoming period, and calibrations required before and after specific science observations.

The EOC will use the long-term science plan to develop a long-term spacecraft operations plan. Subsystem maintenance activities, subsystem calibrations, and spacecraft orbit adjustments must be planned around science operations. These activities will infrequently occur and hence the long-term spacecraft operations plan is expected to be relatively straightforward. The EOC will inform the Project Scientist and the PIs/TLs of any changes in the spacecraft operational performance as well as upcoming spacecraft maintenance activities that may affect science operations.

Short Term Planning:
Short-term planning may be required on occasion to perform needed adjustments to portions of the long-term plan. These adjustments may be needed to support newly created science campaigns (although most science campaigns fall under long-term planning) or to observe the long-term impacts of recent TOOs (e.g., oil spills or volcanic eruptions). Changes may also be required as a result of spacecraft resource limitations caused by onboard anomalies. Changes that greatly impact the long-term plan may trigger the need for an unscheduled IWG to revise science objectives and the long-term plan. Short-term planning will be coordinated among the Project Scientist, the PIs/TLs, and the IIs.

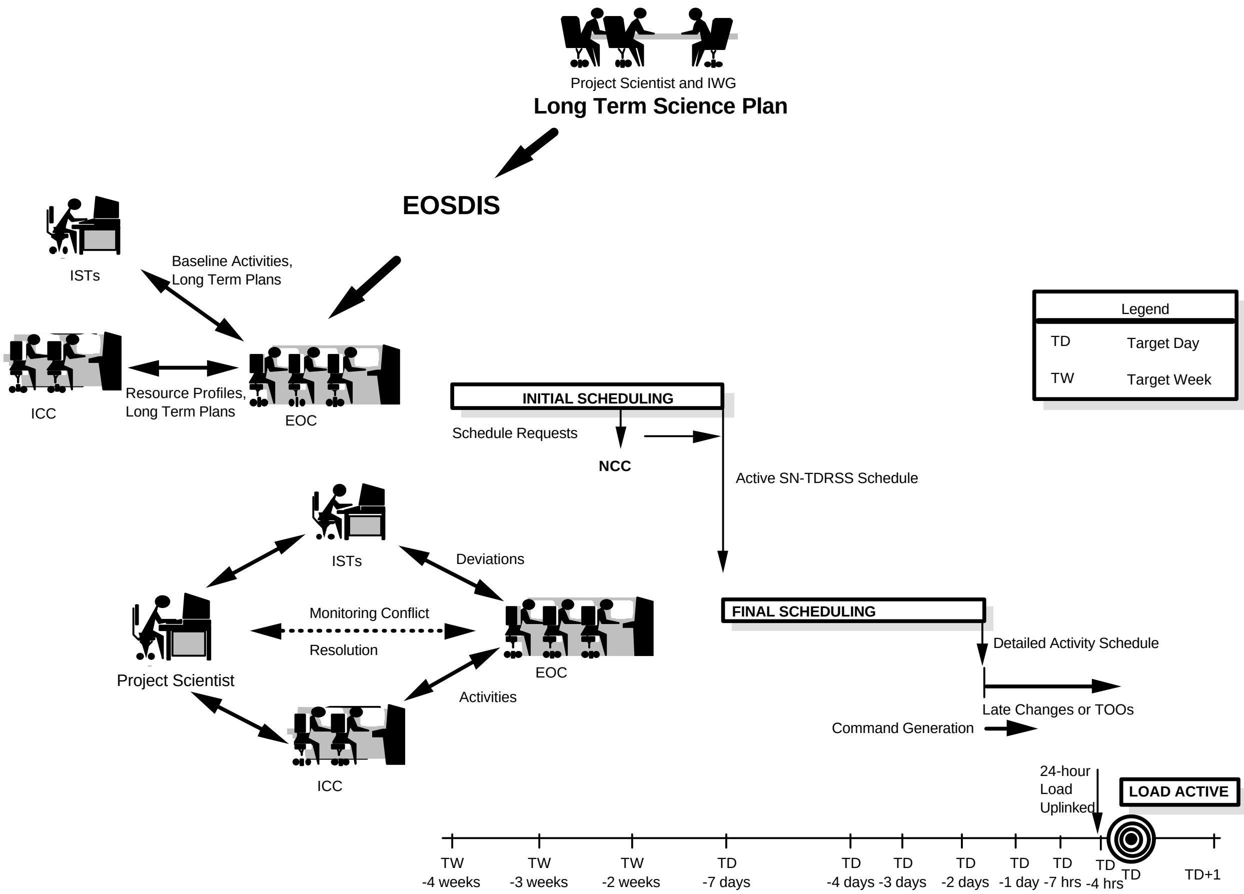


Figure 3.6-1 Overview Of EOS Mission Planning And Scheduling

Initial Scheduling:
The ability to maximize science operations is largely influenced by the proficiency of the planning and scheduling personnel (spacecraft and instruments) in developing a schedule that has each instrument effectively maximizing its scientific return. The schedule must also have the spacecraft effectively using the limited space-to-ground resources (i.e., EOS ground stations or SN/TDRSS).

Prior to each spacecraft launch, spacecraft resources will be allocated to each instrument. It is therefore anticipated that little or no resource contention should occur among the instruments. The primary purpose of initial scheduling will be to resolve conflicts among requests for instrument observation time. This is particularly critical for complex instruments, where late TOOs could conflict with existing scheduled activities. Initial scheduling also provides the FOT with early scheduling data with which to perform data management by assessing the required SN or EOS ground station resources based on onboard recorder usage.

Initial scheduling will begin 3 weeks before the Target Week (TW) (the week being scheduled), resulting in a schedule request to the NCC for TDRSS services at approximately TW - 2 weeks. [Scheduling of AM1 and proposed {post AM1} EOS ground stations will occur during this same timeframe.] For either TDRSS or X-band contacts, scheduling within the multi-mission era should attempt to resolve any EOS spacecraft conflicts (e.g., AM-1 and CHEM-1 requesting the same contact period) internally before requesting the service.

For complex instruments, the ICC is responsible for providing the EOC with the operating schedule and data rate profile for the TW. An IST will provide the EOC with any schedule deviations for non-complex instruments. The EOC will factor in the spacecraft's subsystem data rate profile to estimate the spacecraft's recorder usage and determine the SN and/or ground station resources required. NCC processing of the EOC schedule request will result in an active TDRSS schedule at TW - 1 week. Details associated with scheduling of EOS [post AM1] ground stations is TBD.

The EOC will also manage other resource requirements during the initial scheduling period, including environmental considerations such as an instrument team's desire to maintain a jitter-free or electromagnetic disturbance-free environment (not anticipated for AM-1), or the justification to cause such disturbances during certain observation periods.

Final Scheduling:
During final scheduling, the initial schedule will be updated as necessary to be compatible with the active EOS ground station or TDRSS schedule (provided by the NCC). Final scheduling will be used to develop a detailed activity schedule to support command generation.

TOOs will be incorporated into the final schedule using the negotiated space-to-ground schedule. TOOs will be added less than 24 hours before an observation if there are no schedule conflicts. TOOs that are requested as late as 1 to 6 hours before an observation will be accommodated through real-time commands if possible. The impact of late TOOs on scheduling and the timeframe for accepting TOOs will be refined as instrument and spacecraft operations scenarios become better defined.

TOOs incorporated into the final schedule may result in the deletion of other planned activities. Attempts will be made to resolve conflicts using any flexibility available in the scheduling process. The EOC will initiate resolutions, with the ICCs and/or ISTs representing the instruments in conflict. The final authority in science conflict resolution will rest with the Project Scientist or his designee. The FOT will consult with the MOM/FOD in resolving conflicts relative to the spacecraft and institutional resources.

3.6.2 Command Operations

Ground commands can include both real-time commands (for immediate execution) and command loads (for storage and delayed execution by the spacecraft onboard computer or the instrument microprocessors). Command loads will allow the spacecraft to operate autonomously for at least 24 hours, although the capacity of the onboard recorders will determine the length of time between contacts before science data are lost. Real-time commands are used primarily to support initial activation, contingency operations, and recorder operations. Normal operations will consist of daily command loads, table loads, and real-time commands for recorder operations. EOS command operations will make use of Relative-Time Sequence (RTS) commands and Absolute Time Command (ATCs) sequences. RTSs and ATCs are sequences of commands, whose content and timing are defined in a table stored within the spacecraft onboard computer memory. The spacecraft will have the capability to inhibit some or all stored commands that have yet to be executed, which will prevent stored commands from interfering with the execution of contingency/emergency commands.

All commands for the EOS spacecraft will be sent through the EOC. Instrument activity schedules (indicating instrument commanding, if required) may be input from the remote investigators' ISTs to the EOC for non-complex instruments. In general, instrument command requests and/or loads originate at the ICCs/ISTs and are transferred to the EOC, while spacecraft subsystem commands and loads originate at the EOC. The EOC may optionally store instrument command groups in a command database, as negotiated with each instrument team.

Many of the activities that occur during a real-time contact are repetitive by nature. In order to provide a high level of reliability while at the same time freeing the operations personnel from repetitive operations, a ground script will be generated to encapsulate the activities that occur during a real-time contact into a time-ordered sequence. These activities are automatically executed during the real-time contact. The scripts will be flexible, allowing operations personnel to deviate from them or inhibit portions of them as needed. Ground scripts will allow operations personnel the freedom to support activities such as anomaly detection and resolution of anomalies by freeing them from routine responsibilities.

Command loads and table loads are generated at the EOC based on inputs from a detailed activity schedule and on data received from FDD (e.g., TDRS State Vectors). The EOC will also receive instrument software loads from instrument teams and spacecraft software loads from the software development facility and will convert them into an uplinkable format. Upon completion of the command generation process, loads will be validated to ensure that they agree with the activity schedule. This validation may consist of the EOC checking the header on the uplink data (e.g., command loads or table loads) to verify that the load is consistent with the activity schedule. Command requests will be sent by the instrument teams in the form of command mnemonics. The EOC is responsible for generating the command bit pattern and performing constraint checking to ensure that the sending of a command does not violate any predefined constraints. The instrument teams at the ISTs/ICCs will be responsible for checking instrument software loads. Certain commands will be identified within the spacecraft PDB as critical commands. Critical commands are those commands that if sent may place the spacecraft into a potentially unsafe condition. These commands will require a “two step” command process, where the command controller must manually okay a critical command for uplinking.

Command execution will be verified as follows:

- Command Operations Procedure-1 (COP-1) protocol will be used to assure error-free transmissions. The EOC forwards all commands to EDOS in the form of Command Link Telemetry Units (CLTUs). EOC creates the physical layer of the COP protocol) by appending an acquisition sequence to the beginning of a command string to ensure bit lock onboard the spacecraft. An idle sequence is inserted between CLTUs to maintain the command link. Alternately, the acquisition sequence may be placed at the front of each CLTU during periods when individual commands are sent rather than a group of commands. Upon correct receipt of the command onboard, the spacecraft generates a Command Link Control Word (CLCW) that is appended to a housekeeping telemetry packet. EDOS strips the CLCW from the telemetry stream and forwards it to the EOC to complete the command receipt process.

- The real-time housekeeping stream will contain information regarding the configuration of the subsystems or instruments in response to command execution. For example, if a command is sent to switch to gain setting A, the telemetry shows "Gain A." All stored commands and table loads uplinked to the spacecraft will be retained at the EOC and compared with the spacecraft dump image to verify uplink integrity. The EOC will generate command history logs and send them to the GSFC DAAC for archival.

3.6.3 EOS Telemetry

The spacecraft will generate five types of telemetry data: housekeeping, engineering, ancillary, diagnostic, and science. Housekeeping data originate in the spacecraft subsystems and the instruments. These data consist of the critical operating parameters necessary to monitor health and safety. The instruments will send their housekeeping data to the command and data-handling subsystem, which will integrate the spacecraft and instrument housekeeping data into the CCSDS housekeeping telemetry packets to be sent to the ground and used by the EOC and ICCs/ISTs for health and safety monitoring.

The engineering data are associated with the operation of the instruments and typically include temperatures, voltages, currents, status, positions, configuration, and instrument processor memory dumps. Engineering data are usually a superset of the instrument housekeeping data in that all the housekeeping parameters either exist in or can be derived from the engineering data.

Ancillary data (a subset of data from the spacecraft subsystems), such as spacecraft orbit and attitude data, will be generated onboard the EOS spacecraft. The ancillary data will be made available by the spacecraft data system to the instruments for use within the instruments' onboard data systems as needed. The ancillary data will be downlinked with the science stream, processed, distributed, and archived as part of the level 0 data sets.

Diagnostic data, which are not normally part of the transmitted housekeeping data, will be collected and downlinked for use in memory load verification, anomaly diagnosis, or performance analysis. These data may include memory dump data, telemetry dwell data, and software-generated diagnostic data.

During normal operations, science data obtained from instrument sensors will be collected and recorded on high-rate recorders for playback via the EOS ground stations (TDRSS for AM-1)* The science data may be downlinked in real-time during instrument checkout periods or for anomaly investigation. Other DAS services (i.e., DB and DL) will downlink selected science data in real-time to users.

3.6.3.1 AM-1 Science Data [Contingency Operations]

Wallops ground station X-band backup sites will be used to downlink science data from AM-1 in the event SN communications interface is lost. Wallops will provide a schedule to the EOC based on the

AM-1 predicted orbit, within 1 hour of call-up. All AM-1 science data will be captured whenever spacecraft is in view. Two northern latitude stations (Fairbanks, Alaska and Spitsbergen, Norway) will be called up to provide X-band science backup support if a permanent failure occurs. The Nascom Division Chief, upon notification by the ESDIS Project Manager or the Mission Operations Manager (MOM) of a declaration of emergency, will immediately notify the carriers (Americom, Domsat etc.) that service is needed ASAP. The “emergency” declaration allows Nascom to forego the standard bidding process normally associated with securing the lowest costs, etc. Based upon previous Nascom emergency call-up experience - an overseas communications installation will nominally require a minimum of 30 days from call-up to User operations.

3.6.3.2 Expedited Data Service

As a result of the re-baselining effort for EOS, the requirements for the EOSDIS to produce higher level [Level 1 and above] quick-look products was deleted and replaced with requirements to produce level zero expedited data sets [EDSs]. During a normal TDRS contact, EDOS captures the Ku-band playback data stream, containing both housekeeping and science data. At the conclusion of the spacecraft contact session, EDOS begins level 0 processing of the data into EDSs, and production data sets [PDSs]. The requirement for EDSs will reside with the IOT, and be included in instrument database updates or command loads as flags to be inserted in the proper data onboard the spacecraft.

Data Processing

The EDOS level zero processing facility [LZPF] provides production data processing and expedited data processing. Expedited data processing, although similar to production data processing, does not remove redundant packets between contacts. Production data processing includes data packets from one or more contact sessions that are sorted, sequenced, counted and quality checked. A production data set [PDS] is generated by deleting redundant packets and adding quality information.. EDS processing focuses on single contact sessions and does not take into account any data received in a previous contact session. Two EDSs could therefore contain the same data. Redundant data within an EDS however, is removed. This redundancy will occur when the same section of the spacecraft recorder is dumped more than once during a single contact session. All contents of an EDS are limited to data received during a single spacecraft contact session. Data packets contained in an EDS are also included in production data processing for the same spacecraft contact session. The EOSDIS Ground System can accommodate, for expedited data processing, a total of two percent of all data received over a 24 hour timeframe.

Nominal Expedited Data Processing

For nominal expedited data processing, a quicklook flag, initiated by the IOT via an updated micro-processor load or command request, is sent to the EOC to set the quicklook flag in the data to be expedited. The EOC in turn, builds the necessary command block to set the quicklook flag and uplinks to the EOS spacecraft via EDOS and the Space Network. In EDOS, the data which is flagged for expedited processing is processed first... EDS processing limits the data staging to a single contact session. Since the data in each EDS is included in a PDS for the same coverage period, the EDS will be deleted by the DAAC once the PDS is received. After 48 hours, the EDS will be deleted from the DAAC regardless of receipt of an associated PDS.

Non-Nominal Expedited Data Processing

There are some non-nominal modes of operations that affect expedited data. During launch and early orbit, the limitations on the 2 % [of total] for expedited data may be relaxed to accommodate instrument activation and calibration. In addition, an instrument problem will impact the normal production processing of that instrument's science data. In this situation, the requirement for expedited data processing may be greatly increased, depending upon the situation. Spacecraft maneuvers and other preplanned events are expected to alter the nominal expedited data processing, as are unplanned events which may occur for which there are no formal procedures to follow. In this case the FOT, in conjunction with the science community, will establish an agreeable level of expedited data necessary.

ASTER Expedited Data
Due to the high data rate of ASTER, the maximum amount of expedited data per spacecraft contact session is one minute [vs. 2%]. The format of EDSs for ASTER is the same as the ASTER PDSs. It is different than the format of EDS for the other instruments. ASTER EDSs will contain multiple application process identifiers [APIDs]. ASTER does not receive EDSs or PDSs made of single APIDs. The ASTER PDS format has been implemented by EDOS and the transmission line bandwidth between the GSFC DAAC and the ASTER GDS will handle data files containing the equivalent of two ASTER scenes per day [per Japanese expedited data requirement].

3.6.4 EDOS Handling of Spacecraft Telemetry

Telemetry from all EOS spacecraft will normally be downlinked to EOS ground stations (TDRSS on AM-1). The data are then forwarded to EDOS. EDOS will provide a variety of return link services for level 0 processing, real-time processing, expedited data processing, and rate-buffered delivery. Real-time housekeeping data will go directly from the EDOS to the EOC/ICC for health and safety monitoring. EDOS will begin sending rate-buffered data to the EOC via file to file transfers within five minutes of the end of a contact session. Data identified (by a flag set in secondary header of the data or verbally) will nominally be sent to the DAAC within two to three hours after the completed contact session. Level 0 processed data sets from EDOS will be delivered to the specified DAACs, and other data facilities as negotiated premission. Rate-buffered data of selected instruments will be delivered to an agreed-upon pickup point for use by NOAA.

3.6.5 Spacecraft and Instrument Health and Safety Monitoring

Monitoring will be performed to ensure the health and safety of the spacecraft and instruments. The sampling interval required by the EOC and the instrument teams for effective health and safety monitoring of spacecraft subsystems and instruments will be determined for each spacecraft.

Instrument Monitoring:
Monitoring of the instrument housekeeping data is required to verify that the instrument is operating within prescribed limits, is safe, and is not adversely affecting spacecraft subsystems or other instruments. ICCs will be primarily responsible for health and safety monitoring of their instruments, with the EOC providing support for health and safety monitoring. Instruments with ISTs will primarily be monitored at the EOC, with instrument personnel using ISTs to support this process. The instrument team may assume primary responsibility during contingency periods or periods of increased instrument activity levels. The EOC will provide raw housekeeping data to the ISTs, which decommutate the data and display it for the instrument teams.

Spacecraft Monitoring:
The EOC will monitor the spacecraft housekeeping data of each spacecraft subsystem for health and

safety and verification of proper subsystem performance. This responsibility includes monitoring all spacecraft subsystems for correct performance, verifying the status of all resources, and detecting any anomalies. The EOC will provide 24-hour support for spacecraft health and safety monitoring. The EOC will provide the capability to perform a limited state check upon initiation of a real-time contact session. Based on expected onboard operations and command executions, the EOC will generate a set of telemetry parameters to predict the current state of the spacecraft. Upon verification of the space-to-ground link, the EOC will automatically compare predicted and actual telemetry and notify the appropriate flight operations personnel of any discrepancies.

3.6.6 Solid State Recorder Management

Large volumes of science data will be collected from the instruments on EOS spacecraft and will be stored onboard using solid state recorders. Solid state recorders provide the capability to assign logical buffers within the storage area. Each buffer can be sized to store science and engineering data from one or more instruments based on a Virtual Channel Identifier (VCID) located within the data headers. Buffers can be played back in any order, providing the operations personnel with greater flexibility during space-to-ground contacts. The size of these recorders will allow science data to be stored for a number of orbits (2 orbits of storage for AM-1) without a ground contact before their capacity is reached and data is lost. There may also be contact periods in which poor space-to-ground links or ground system errors result in the need to replay portions of the recorder before data is overwritten and lost. Thus, the management of this limited spacecraft resource is essential to ensure that all science data collected is downlinked and processed by the ground system. To accomplish this task, spacecraft housekeeping telemetry, along with operations management data generated by EDOS, is analyzed. The EOC will develop a software model for each spacecraft's recorder in order to accurately predict the volume of data onboard. This tool will be used during planning and scheduling in order to adequately space ground station and/or TDRSS contacts based on planned observations. During real-time contact periods, the predicted volume of data in each buffer can be compared to actual values to aid in determining if an anomaly occurred during the back orbit. The real-time data and operations management data are fed into the model in order to update it and to allow it to provide suggested playback commands or to replay portions of the buffers that were missing or of poor quality.

3.6.7 Performance Monitoring and Assessment

Instrument Monitoring:

The instrument teams, via their ISTs, will be responsible for sustaining engineering and maintenance of their instruments. Sustaining engineering is an ongoing assessment of instrument performance that is obtained by analyzing selected housekeeping and engineering data in conjunction with the results of monitoring activities. Adjustments will be made, if possible, to the instrument to maintain predetermined performance parameters. The instrument teams will perform trend analysis over varying time scales of instrument operations. This function will allow degradations in instrument performance to be recognized before they become irreversible and will allow re-evaluation of instrument resources for a degrading but still functioning instrument. Instrument teams may request engineering data and analysis products from the EOC to support their performance analysis. The EOC is responsible for obtaining the engineering data from the DAACs and providing the ISTs with analysis reports or the raw engineering telemetry for decommutation and analysis by the instrument teams.

Spacecraft Monitoring:
The FOT at the EOC will track and control the allocation and rate of use of spacecraft resources to maximize a spacecraft's useful life and scientific data return (some of the spacecraft resources monitored are shown in Figure 3.6-2). This task may be simplified depending on the spacecraft. For instance, the only anticipated initial resource tracking expected for AM-1 is the storage of data within the solid state recorders. The FOT will evaluate subsystem performance and subsystem trend analyses to determine requirements for spacecraft calibrations and to identify potential problems in upcoming spacecraft calibration support. The FOT will use spacecraft analysis tools for short-term and long-term assessment of spacecraft performance. Additionally, the spacecraft developer may provide specialized spacecraft analysis software to assist in these tasks. The FDF will provide orbit and attitude evaluations to enable an overall assessment of spacecraft performance.

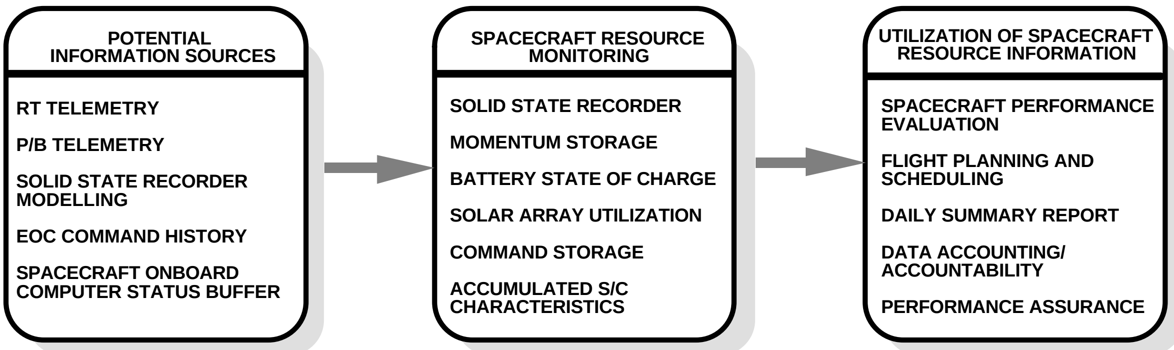


Figure 3.6-2 Overview of EOS Spacecraft Resource Tracking

3.6.8 Data Quality Assurance and Data Accounting/Data Accountability

Effective data quality assurance and data accountability demand near real-time collection of status and quality statistics from the different data handling and processing phases from the moment the data are generated onboard the spacecraft.

Data Quality Assurance:
If the quality of the downlinked data is unacceptable, an orderly investigation into the cause of the degradation will be conducted. If the problem is traced to the spacecraft, the EOC and/or ICCs/ISTs will initiate appropriate operations procedures to command the spacecraft and/or instruments to correct the problem. EDOS and the NCC are the primary source of early data quality checks. EDOS will provide accounting, status, and quality statistics to the EOC in the form of Customer Operations Data Accounting (CODA) reports every 5 seconds during a contact session and the NCC will provide the EOC with User Performance Data (UPDs). In addition, management information regarding EBnet operations is included in the CODA to provide the EOC with the status of the EBnet network in order to determine if the loss or degradation of the data is caused by the ground.

Data Accounting/Data Accountability:
End-to-end data accounting is a requirement that can be accomplished if both the onboard data system and the ground system designs include enough information in the telemetry to perform this function effectively. Data accounting will be performed for all data received and processed through EDOS and acquired at the EOC and the DAACs.

The instruments will be designed to send information in the telemetry (engineering data stream) to support data accounting/data accountability. This information will help the ICC/IST to determine unambiguously what data are being generated by the instrument at all times. This information will be used in EOSDIS, along with logs and operations schedules, to ensure that all data generated onboard are received and processed on the ground. Accounting and accountability for all EOSDIS data products will be performed by the elements that produce them. The SMC will perform system-wide accounting and accountability. Data accounting/data accountability reports will be sent to the DAACs for archival and distribution.

3.6.9 Data Archival and Distribution

Many data types and processing results require on-line (short term) and off-line (long term) storage within the EOS ground segment to support operations. Timely access to recent data are required to support spacecraft and instrument health and safety and performance evaluations or to obtain data lost due to communications outages. Data will be primarily stored at the EOC, the EDOS and the DAACs. All EOS telemetry (see Section 3.6.3) will be level 0 processed by EDOS and stored as archived data sets. This data includes the housekeeping and associated ancillary data , engineering and diagnostics data, and the science data.

Short Term Storage:
The EOC will provide short-term storage of operations history data such as spacecraft schedules, command logs and housekeeping and engineering data. The data will be transferred to the GSFC DAAC when the FOT doesn't anticipate a need to retrieve the data quickly. Operations history data will be normally stored in the EOC for about 7 days, but may remain longer if it is considered necessary.

EDOS will provide on-line storage (for up to 30 days) of level 0 data for timely retransmission of selected data sets, if requested.

Long-Term Storage:
The EDOS will provide a backup archive of level 0 data products for the life of the EOS mission plus 3 years. The DAACs will be the primary archive for level 0 or level 1a data products. Long-term storage of higher level products and their distribution are discussed in the EOS Science Operations Concept document.

3.6.10 EOSDIS Backbone Network

The EOSDIS Background Network (Ebnet) provides mission network communications involving the transport of operational real-time data required for command and control of the EOS spacecraft and the transport of level 0 production science data sets to the DAACs and international gateways. Ebnet services are dedicated to providing connectivity among the DAACs for transporting bulk data orders to other DAACs.

The NSI network provides essential external network services. The NSI provides the required services to accomplish the quality assurance functions at the designated science investigator sites. NSI also provides connectivity among users, facilities and EOSDIS.

Each network will be managed by the organization providing the communications network. Specifically Ebnet and NSI will manage their own network. The SMC will receive copies of trouble tickets from both network management centers. Trouble ticket information will be exchanged among respective network entities when the problem resides outside a given network.

3.6.11 System Management

The SMC will provide a system-wide view of EOSDIS operations. The SMC provides for system-wide coordination of activities at individual site or element locations through its high-level cognizance of and direction on resource configuration. This coordination ensures that the ground system activities and resources needed to successfully conduct science operations are properly and efficiently shared among elements. More details regarding SMC operations can be found in the Science Operations Concept document.

Local System Management (LSM) services are provided at sites within the EOS Core System (primarily the EOC and the DAACs) to coordinate management activities between sites and with the SMC. The LSM allows the SMC to monitor ground operations at the sites in order to evaluate items such as ground system resource usage and system performance. This information may be used to develop and alter the system policies and procedures used to maximize the overall system performance.

3.6.12 Operations Management Data

Operations Management Data (OMD) are used to manage operations and interfaces within various segments of the ground system and to perform system monitoring and coordination. OMD are required during real-time operations for verifying real-time interfaces through test messages and for performing fault identification, isolation, and recovery. For non-real-time operations, OMD are used for data accounting, system performance monitoring, service requests, and for transferring delivery records, schedules, summary reports, and more. Decisions involving the type of information contained within OMD must be well thought out at both the segment level and the system level. Data must be chosen to allow the above real-time and non-real-time activities to be performed in the most efficient manner.

3.7 CONCEPTS FOR CONTINGENCY OPERATIONS

Contingencies can result from anomalies or faults associated with the space and ground segments and/or the space-to-ground communications links.

3.7.1 Spacecraft Contingency/Emergency Operations

Anomaly/Fault Detection and Isolation:

The spacecraft will provide various levels of automatic and manual detection and recovery from faults. Spacecraft onboard computer systems, with operations support from the FOT, will perform a set of fault detection and isolation operations. The number of automatic operations performed will be based on the capability of the onboard computer to safely perform the necessary corrections or alternatively to place the spacecraft into a safe mode.

Alternative Spacecraft Operations Modes:
During its operations phase, a spacecraft may transition into various degraded modes of operation to perform spacecraft maintenance or orbit adjustment, if required. Under certain failure scenarios, the spacecraft may switch to a safe mode (when the spacecraft onboard computer fails or is not performing correctly) or a survival mode (when available power to the spacecraft is limited due to an anomaly). Under these conditions, the spacecraft subsystems and instruments are placed into a relatively

benign mode and the overall spacecraft may be maneuvered into a power-positive orientation. The spacecraft can enter a safe or survival mode from all other modes or from ground control of the on-board logic. Return to normal operations will require manual intervention at the EOC to ensure proper spacecraft function before mode transition.

During degraded modes of operation, the EOC will require increased support from the appropriate subsystems engineers, and possibly the spacecraft simulator, for fault detection, isolation and recovery. Increased use of the SN and GN/WOTS for data analysis and commanding may also be required.

3.7.2 Space-to-Ground Contingencies/Emergencies

To support contingency/emergency operations, the spacecraft will use the TDRSS, the GN and the WOTS. Operations using these ground elements are solely for spacecraft and instrument commanding and for spacecraft and instrument health and safety monitoring.

Direct Playback (DP) Contingency for AM-1
The DP will be used as a science data backup mode for the AM-1 spacecraft in the event of an extended or permanent loss of the normal high-rate link. The primary method of data retrieval will be via the DP service, which will downlink all data from the high-rate recorders to selected EOS X-band ground stations.

3.7.3 Ground System Contingencies

Ground System Redundancy:
Developing adequate redundancy within the ground system hardware is of particular importance to maintaining ground system operability. The EOS flight operations components will be designed to ensure adequate redundancy within the ground system and the operations network that links them. Systems that perform real-time functions will maintain a high reliability, maintainability and availability (RMA) level (e.g., RMA for the EOC is 0.9998). External ICCs will need to provide adequate redundancy in their own ground systems. The EOC, however, will perform critical instrument health and safety monitoring as a backup to ICC monitoring. The EOC will also store instrument commands to be uplinked under certain instrument contingency scenarios, as negotiated with each of the instrument operations teams. Communications reliability is also a critical element for flight operations. Within elements of the ground system, redundancy must be provided to ensure automatic transition to backup networks. For example, the EOC network will operate using dual FDDI rings on both operational and support LANs. The support network will handle non-real-time functions to ensure efficient network use by segregating traffic (e.g., spacecraft analysis, I&T, and FOT training). Since hardware can be connected to both the operational and support LANs, a high level of availability can be maintained. EBnet will also provide a high level of reliability to ensure delivery of data between the mission critical components (e.g., EDOS, EOC, DAACs).

Anomaly Detection and Resolution Operations:
EOS operations personnel will be exposed to a variety of anomalies due to hardware and software problems as well as operational errors. A number of steps may be taken to respond to a particular problem and return to normal operations quickly but safely. The first two of these steps are fault detection and isolation. The ground system will be developed to provide operations personnel with ground-generated telemetry containing the information needed to not only quickly detect anomalies but to isolate the component responsible for the problem. Faults within components that affect the system will be autonomously recovered if possible. If not possible, fault accommodations must be

performed to activate a temporary work-around until the normal state can be restored. Fault analysis may involve the formation of "tiger-teams" to bring together experts in the specific area of the problem. Once a fault has been analyzed and a resolution proposed, the resolution will be validated if possible to ensure correctness before bringing the system back on-line. Any newly developed commands or procedures must be written and signed off by the responsible subsystem engineers, the instrument operations team (if applicable), and the Flight Operations Director (FOD) before they are performed or uplinked. Finally, certain resolutions may require follow-up testing to ensure that the component is operating as expected and that systems operations are not adversely affected.

Contingency Procedures:
In addition to losing science data because of spacecraft anomalies, problems during ground system operations may also cause valuable science data to be lost. These problems may be greatly reduced by using contingency operations procedures for anomaly conditions that have been anticipated and for which solutions have been validated. Contingency procedure development will be a coordinated effort of the flight and instrument operations teams and their respective engineering teams. The procedures will be verified using spacecraft simulators whenever possible. Responses to anticipated contingencies may be initiated using planned and validated procedures for spacecraft check-out, verification, and normal operations. These procedures provide the capability for quick response in the event of an anomaly.

Software resident in the EOS ground segment will be designed to allow semiautomatic execution of preset procedures or operational sequences. Command procedures and telemetry displays will be rebuilt and stored. If a need arises, the operator may modify command procedures before transmission. Not all contingency cases can be predefined and, in certain cases, workaround procedures will have to be developed and operations alert messages issued. If the workaround procedure needs to become a permanent procedure, the operations alert will be deleted once the modification is validated and approved by the configuration control board.

3.8 CONCEPTS FOR SPACECRAFT CROSS-OVER OPERATIONS

It is expected that spacecraft will be replaced while resources are sufficient to allow the spacecraft to remain operable during the 6-month crossover period. The old spacecraft will be replaced by a new spacecraft containing instruments that examine the same basic phenomena as the old spacecraft. The replacement spacecraft will be delivered to the operational orbit, and every effort will be made to keep the old spacecraft operational until the replacement spacecraft has been verified as operational and all necessary cross-calibration has been performed. During this period, both spacecraft will be performing concurrent operations. One hundred percent of the housekeeping and science data will be downlinked during this period. Appropriate procedures and safeguards will be followed to prevent adverse impacts on ground system and spacecraft operations. Operations will be closely coordinated between spacecraft to minimize the additional load on the ground system components and the network traffic.

The transition of operations from the operating spacecraft to the replacement spacecraft will be accomplished in a controlled fashion. Once the spacecraft subsystems and instrument operations have been verified and cross-calibration completed on the replacement spacecraft, the replaced spacecraft will be placed in a safe mode configuration. EOS spacecraft will be disposed of according to NASA Management Instructions (NMI).

SECTION 4. OPERATIONS ORGANIZATION AND MANAGEMENT

4.1 THE EOS MISSION OPERATIONS STAFF

The EOS mission operations staff is led by the MOM. The EOS MOM has responsibility for overall EOS mission operations. The MOM develops mission operations concepts and requirements, and coordinates the development of a total mission operations system. The MOM coordinates mission operations support among the various EOS flight projects, the MO&DSD institutional elements, and the ESDIS Project. The MOM is responsible for coordinating mission operations planning and interfacing between the spacecraft developer, external flight operations elements such as the ASTER ICC, and the ECS flight operations personnel. The MOM coordinates FOT training at the EOC, conducts prelaunch simulations and readiness exercises, and prepares the mission operations system for launch. After launch and spacecraft verification, the MOM has overall responsibility for the operation of all EOS spacecraft to fulfill the mission objectives.

The OMs for each flight project provide flight operations concepts and requirements for each spacecraft and provide spacecraft-specific training for the FOT. The OMs arrange for training for the FOT in the design and operations of their respective spacecraft. The OMs support all prelaunch activities through launch plus approximately 3 to 6 months for each spacecraft within a series.

The EDOS and EBnet Project Managers are responsible for the development of EDOS and EBnet elements. It is also the responsibility of these managers to name operations managers for each element, who in turn will be responsible for ensuring operations training and day-to-day operations. The staffing plans for EDOS and EBnet are currently to be determined and will be developed as each element progresses through its design phase.

An FOD is assigned for each spacecraft and is the central point of contact for day-to-day decisions concerning spacecraft operations and resources. This provides an independent advocate for each spacecraft to ensure that resources are distributed equitably. The FOD consults with the MOM, the OM (as needed) and Project Scientist or his/her designee as necessary to resolve conflicts.

A Flight Operations Manager [FOM] will be provided by the operations and maintenance contractor and will advise the MOM on the overall status of the EOC and the ISTs. The FOM has overall responsibility for all FOT technical and management functions. External ICCs, such as the ASTER ICC for AM-1, will be responsible for designating an operations manager to work with the MOM and the FOM on any ICC issues that arise that may impact the ICC or FOS.

Other on-line and off-line management positions will be responsible for such activities as spacecraft engineering, configuration management, FOT training, and administration. These positions will be defined as the design phase matures.

The FOD is supported by various on-line and off-line operations support personnel. The on-line flight operations staff consists of a spacecraft operations supervisor, a command controller, and spacecraft and instrument health and safety evaluators. The on-line staff are located at the EOC. Operations support personnel at the EOC include a planning and scheduling staff and all normal operations support personnel (e.g., logistics personnel). The planning and scheduling and operations and engineering support personnel for the instruments perform and/or support operations through the ICC or the ISTs. These individuals may include the PIs, Co-Is, TL/TMs, instrument teams, and instrument sustaining engineering and maintenance teams. The spacecraft sustaining engineering and maintenance staff will include engineering personnel with expertise in spacecraft subsystem or instrument hardware and software. Subsystem engineering personnel are initially provided by the spacecraft developer and may reside at the spacecraft developer's facility after spacecraft checkout.

4.2 MULTIPLE SPACECRAFT OPERATIONS STAFFING CONCEPTS

The flight operations team staffing philosophy advocates extensive cross-utilization of individuals on more than one spacecraft for increased efficiency and cost effectiveness. Cross-training for the various positions increases flexibility of the overall team and reduces the impact of contingency operations. As discussed earlier, as many as four EOS spacecraft will be on-orbit simultaneously. The cross-utilization of operations personnel is a concept that should be implemented only after the launch, checkout and verification period has been completed and the on-orbit operation of the spacecraft is fully understood.

There are several factors that must be weighed when determining the extent to which operations personnel can perform operations functions for multiple spacecraft. First, can the ground system architecture support a multispacecraft operations philosophy? The architecture must be robust enough so that workstations can connect to multiple spacecraft strings. As was discussed in Section 3.3.1, the flight operation architecture will provide such a framework. User workstations can connect to multiple logical strings, with each logical string representing a different spacecraft or operations process. Second, to what extent is there commonalty across the many EOS spacecraft and instruments? EOS PM-1 and CHEM-1 will be developed using a common spacecraft bus. Therefore, the amount of cross-utilization should be significant for these spacecraft. If all EOS spacecraft are designed to provide commonalty whenever feasible, then the number of operators required for all spacecraft may be significantly reduced. Although the LALT spacecraft are significantly smaller than the other EOS series, commonalty within certain spacecraft subsystems may be possible (e.g., communications subsystems). A number of EOS instruments are manifested on multiple spacecraft. This should allow a multi-instrument operations concept to be used. The third item is an unknown factor, the stability of spacecraft and instrument operations. If instruments and spacecraft subsystems are performing as expected, operations personnel will be able to handle multiple functions. If the spacecraft and or instruments are not performing nominally, then a dedicated staff is needed to ensure spacecraft and instrument health and safety.

The factors above influence all flight operations functions, although the overall complexity of each function is somewhat different. The possibility of multiple spacecraft operations in planning and scheduling, commanding, health and safety analysis, performance analysis, and sustaining engineering are discussed in the following paragraphs.

Planning and Scheduling:
The extent to which operations personnel can provide scheduling services for multiple spacecraft and instruments will depend somewhat on the commonalty among instruments and spacecraft, but to a greater extent it will depend on the overall complexity in the operations of the instruments. Targeting instruments require dedicated schedulers to constantly update and refine observation periods. As discussed in Section 3, an initial look at the current EOS manifest indicates that most of the EOS instruments are “non-complex” in terms of the amount of ground interaction required to perform observations. Thus, baseline activity profiles will be the normal method of scheduling instrument observations, with few deviations expected. This limited amount of scheduling will allow schedulers to be assigned to multiple instruments on multiple spacecraft. Before additional spacecraft are

launched and operational, a careful study should be undertaken to determine how best to divide the scheduling of “non-complex” instruments. In addition to the cost savings provided by cross-utilization, certain scheduling functions may be most efficiently performed by a limited number of schedulers. The scheduling of EOS ground stations and TDRSS contacts for all EOS spacecraft should be internally conflict free before the contact periods are requested. This concept will hopefully reduce the iterative process of resolving conflicts with a third party such as the NCC when the conflict is between two or more EOS spacecraft.

Commanding:
The commanding of multiple spacecraft by the same real-time controllers may be thought of as too great a risk to the health and safety of the spacecraft due to the criticality of the operations function itself. The concept may be possible if the scheduling of EOS spacecraft contacts is spaced to allow adequate time for the operators to end one session and sufficiently prepare for the next. However, the concept of scheduling contacts to reduce the number of operators will introduce another variable for schedulers to manage and hence should only be considered if scheduling is considered an easy task to perform.

Spacecraft and Instrument Health and Safety and Performance Analyses:
The real-time spacecraft and instrument health and safety evaluators are similar to the command controllers in that there must be enough operators to handle concurrent real-time contacts. The commonality among spacecraft and instruments will be a large factor in determining the total number of evaluators needed. An evaluator may also perform additional non-real-time tasks (e.g., subsystem trend analysis) as well as performance analysis tasks. Most of the instrument performance analysis will be performed by the instrument teams using ISTs at their home facilities.

Sustaining Engineering:
The sustaining engineering staff consists of off-line subsystem experts required when anomalies occur or when they must perform functions such as flight software updates. The commonality of the EOS spacecraft will be a major factor in reducing the number of sustaining engineers required for all EOS spacecraft.

SECTION 5. OPERATIONS SUPPORT

5.1 GROUND SYSTEM CONFIGURATION AND MAINTENANCE

The DSM is responsible for the development of the MO&DSD institutional elements to meet mission requirements. The ESDIS I&T manager is responsible for end-to-end integration testing and validation of the EGS. The MOM, with the aid of the FOD (one for each mission) and the ESDIS I&T Manager, is responsible for the operational readiness of the various mission operations elements of the MO&DSD ground system and the EOSDIS, and coordinates operational readiness tests and simulations. The I&T Manager defines and verifies the interfaces among EOSDIS elements and among internal and external elements and facilities. The respective organizations within the MO&DSD prepare procedures for operations maintenance and configuration control for the functional elements. Operations manuals are prepared detailing normal operations procedures, procedures for alternate or backup operations in cases of failure, and procedures for preventive and corrective maintenance.

The MOM assists the DSM in reviewing plans for facilities (i.e., space allocations, power needs, and communication needs), particularly the new EOS facility at GSFC, to ensure their suitability for operations. The MOM defines the top level procedures for mission operations, ground system maintenance, and configuration control and establishes the overall mission operations team. The spacecraft contractor provides the Spacecraft Data Base (SDB), spacecraft simulator, and other information needed for ground system operation of the spacecraft.

The configuration of all elements is frozen at the time of operational acceptance and then maintained by the respective organizations. The ESDIS Project CCB maintains configuration control of all the EOSDIS elements. The EOSDIS elements developed by the MO&DSD (i.e., EDOS and EBnet) maintain configuration control for specific elements through divisional CCBs and work with the ESDIS Project CCB for configuration control items affecting the Level 2 requirements, schedule and cost.

5.2 FLIGHT SOFTWARE MAINTENANCE AND VERIFICATION

Configuration-controlled procedures are used to maintain the flight software for the spacecraft and instruments. A software development facility will initially be operated by the spacecraft developer to maintain the spacecraft flight software and to create updates as needed. The responsibility of this task will transfer to GSFC Flight Software Systems Branch (Code 512). Any changes to the flight software are validated before uplinking the software for execution. Change control is enforced by a Project Configuration Control Board (CCB) to ensure that all changes are proper and that earlier versions of the software are available if anomalies are identified in subsequent versions. A flight software testbed may be used to validate planned updates to the spacecraft flight software.

Instrument microprocessor flight software will be maintained by the instrument teams at the ICCs and/or ISTs, who will perform configuration control and validate changes to the software loads. Once the loads are validated, they are transferred from the ICC (or from an IST in the case of less complex instruments) to the EOC for uplink. The EOC will validate correct instrument destination, check for hazardous commands, and verify correct uplink of the loads to the spacecraft.

5.3 CONFIGURATION MANAGEMENT

The EOS ground system operation resources are controlled through a Configuration Management (CM) process. Various sites within the ground system (e.g. EDOS, EBnet, EOC/ISTs, and DAACs) will be responsible for maintaining the configuration of their respective hardware and software components, along with other areas such as documentation and facilities. The ESDIS CCB is responsible for maintaining system-level configurations. Individual sites will also be responsible for adopting their own local change procedures, which must be consistent with ESDIS CM policies. Changes at the sites will be sent to the SMC so that they may be documented in a central location. Changes at the local level that may benefit other sites may be considered for system-wide implementation.

Additionally the ESDIS CCB will delegate responsibility and authority to the ESDIS Flight Operations (FO) CCB to control Flight Operations Team (FOT) developed files, FOT procedures, display pages, Project Data Bases (PDBs), as well as any other items requiring control by the FOT. The CCB will be chaired by the Mission Operations Manager with appropriate representation from the FOT and FOS development representatives. The ESDIS FO CCB CMO will be responsible for retaining and maintaining the listing of items to be controlled and FO CCB procedures. The FO CCB will use the ESDIS CCR form. Any changes affecting ECS Level 3 requirements (which include FOS) will be submitted by the FO CCB to the ESDIS CCB for approval.

Project Data Base Maintenance:
A separate operational PDB will be developed for each EOS spacecraft. The spacecraft developer will provide the spacecraft I&T database before launch as the foundation of the PDB. Each PDB consists of one or more databases pertaining to the spacecraft and its subsystems, the instruments, and the operation of the spacecraft as a whole. Contents of the PDB include elements such as telemetry format definitions, commands and identification of critical and hazardous commands, data conversion factors and formulas, limits, images of flight software data tables, and copies of predefined relative-time command sequences stored onboard the spacecraft. The FOT may make temporary, ad hoc changes to certain parts (e.g., to existing limits or existing calibration curves) of operational copies of the PDB; however, the MOM or his/her designee must initially approve all temporary changes. Permanent changes must be submitted to the Flight Operations CCB for approval before implementation. Permanent updates to the PDB must be validated and verified before they are submitted for approval. The Mission Operations Management Team ensures that proper approval procedures are followed in the execution of mission operation maintenance activities, including the maintenance of the PDB.

Documentation Preparation and Maintenance:
A very large volume of reference information will be necessary to prepare and sustain the EOS flight operations over the planned 20-year lifetime. The spacecraft contractors will provide the FOT with the following types of documentation: subsystem descriptions and detailed diagrams, subsystem data books, O&M manuals, flight software documentation, spacecraft databases used during I&T, and FOT training material. The ESDIS Project will provide documentation for EOSDIS. Each instrument PI/TL will provide all necessary operations scenarios and procedures documentation to the ESDIS Project so that the EOC may support instrument operations as specified before launch. These procedures include all limit or constraint checking necessary to monitor instrument health and safety. During on-orbit operations, the PI/TL will provide the EOC with updates to existing

documentation as necessary. Should EOC instrument operational responsibility increase during the flight, additional documentation to perform those functions will be provided by the PI/TL.

During spacecraft operations, the FOT will provide periodic performance and activity reports to the project. These data will be used to evaluate the performance of the spacecraft and to ensure that future spacecraft are modified or enhanced based upon the current spacecraft's performance. This documentation is also used to support initial and recurrent training of operations personnel, training of replacement personnel, problem identification and resolution, and system modifications and enhancements. A thorough, accurate, and useful reservoir of reference information will be developed and maintained to ensure the integrity of systems knowledge throughout the more than 20-year EOS mission lifetime. This is best achieved through the establishment and enforcement of uniform standards for documentation, ease of access and maintenance, and control over changes and updates. Operations reference documentation will be provided on both electronic and hard copy media.

5.4 MISSION MONITORING

Mission monitoring will be performed to determine if the spacecraft and the ground system are being effectively used to meet the overall mission objectives. As discussed in Section 3.6.1, the Project Scientist and the IWG develop a long-term science plan that describes the science priorities and objectives for each flight. This plan is the foundation for the planning and scheduling process, culminating in the observations made by the instruments. A large part of mission monitoring centers on evaluating the responsiveness of the actual observations to the long-term instrument and science plans. The Project Scientist determines if the guidelines and priorities laid out in those plans are being correctly applied and interpreted and if adjustments are needed to subsequent versions of the plans. Another portion of mission monitoring involves evaluating whether or not ground system operations can be adjusted to maximize science return. For example, it may be determined through comparing the instrument schedules to the actual observations that a 24-hour planning and scheduling staff would greatly increase the operations responsiveness to TOOs.

APPENDIX A - ACRONYM LIST

ACRIM	Active Cavity Radiometer Irradiance Monitor
ADC	Affiliated Data Center
ADEOS	Advanced Earth Observing Mission
AIRS	Atmospheric Infrared Sounder
ALT	Altimeter
AMSU	Advanced Microwave Sounding Unit
APID	Applications Process Identification
ASF	Alaska SAR Facility
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATC	Absolute Time Command
bps	bits per second
C&DH	Command and Data Handling
CCB	Configuration Control Board
CCSDS	Consultative Committee for Space Data Systems
CERES	Clouds and Earth's Radiant Energy System
CHEM	Chemistry
CIESIN	Consortium for International Earth Sciences Information Network
CLTU	Command Link Telemetry Unit
CLCW	Command Link Control Word
CODA	Customer Operations Data Accounting
Co-I	Co-Investigator
COP	Command Operations Procedure
CSA	Canadian Space Agency
CTV	Compatibility Test Van
DAAC	Distributed Active Archive Center
DADS	Data Archive and Distribution System
DAR	Data Acquisition Request
DAS	Direct Access System
DB	Direct Broadcast
DDL	Direct Downlink
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DP	Direct Playback
DPWG	Data Processing Working Group
DPR	Data Processing Request
DSM	Data Systems Manager
EBnet	EOS Communications
ECS	EOSDIS Core System
EDC	EROS Data Center

EDOS	EOS Data and Operations System
EEDSOG	End to End Data Systems Operations Group
EM	Equipment Module
EMOWG	EOS Mission Operations Working Group
ENG	Engineering
ENVISAT	Environmental Satellites
EOC	EOS Operations Center
EO-ICWG	Earth Observing International Coordination Working Group
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EOSP	Earth Observing Scanning Polarimeter
EROS	Earth Resources Observation System
ESA	European Space Agency
ESDIS	Earth Science Data and Information System
ESN	EOSDIS Science Network
ETS	EOS Test System
FDD	Flight Dynamics Division
FDF	Flight Dynamics Facility
FOD	Flight Operations Director
FOR	Flight Operations Review
FOS	Flight Operations Segment
FOT	Flight Operations Team
GCRP	Global Change Research Program
GGI	GPS Geoscience Instrument
GISS	Goddard Institute for Space Studies
GLAS	Geoscience Laser Altimeter System
GN	Ground Network
GSFC	Goddard Space Flight Center
GSIWG	Ground System Integration Working Group
H/K	Housekeeping
H&S	Health and Safety
HGA	High Gain Antenna
HIRDLS	High-Resolution Dynamics Limb Sounder
HIRIS	High-Resolution Imaging Spectrometer
I&T	Integration and Test
ICC	Instrument Control Center
ICD	Interface Control Document
IET	Instrument Engineering Team
IFWG	Interface Working Group
I I	Interdisciplinary Investigator
IMS	Information Management System

IP	International Partner
IPDC	International Partner Data Center
IPGS	International Partner Ground System
IST	Instrument Support Terminal
IV&V	Independent Verification and Validation
IWG	Investigator Working Group
JPL	Jet Propulsion Laboratory
J-EOS	Japanese Earth Observing System
kbps	kilobits per second
km	kilometer
KSA	Ku-Band Single Access
LALT	Laser Altimetry
LAN	Local Area Network
LaRC	Langley Research Center
LCP	Left handed Circular Polarization
LRR	Launch Readiness Review
LSM	Local System Management
M	Meter
MA	Multiple Access
Mbps	Megabits per Second
MCST	MODIS Characterization Support Terminal
METOP	Meteorological Operational Satellite
MHS	Microwave Humidity Sounder
MIMR	Multi-Frequency Imaging Microwave Radiometer
MISR	Multi-Angle Imaging Spectro-Radiometer
MITI	Ministry of International Trade and Industry
MLS	Microwave Limb Sounder
MO&DSD	Mission Operations and Data Systems Directorate
MODIS	Moderate-Resolution Imaging Spectrometer
MOM	Mission Operations Manager
MOMP	Mission Operations Management Plan
MOPITT	Measurements of Pollution in the Troposphere
MRM	Mission Readiness Manager
MSFC	Marshall Space Flight Center
MTPE	Mission to Planet Earth
NASA	National Aeronautics and Space Administration
Nascom	NASA Communications Network
NASDA	National Space Development Agency (Japan)
NCAR	National Center for Atmospheric Research
NCC	Network Control Center

NESDIS	National Environmental Satellite, Data and Information Service
NMI	NASA Management Instruction
NOAA	National Oceanic and Atmospheric Administration
NREN	National Research and Educational Network
NSI	NASA Science Internet
NSIDC	National Snow and Ice Data Center
O/A	Orbit Attitude
O&M	Operations and Maintenance
ODC	Other Data Center
OM	Operations Manager
OMD	Operations Management Data
ORR	Operations Readiness Review
OJT	On-the-Job Training
OWG	Operations Working Group
P/B	Playback
PDB	Project Database
PDF	Programmable Data Formatter
PGS	Product Generation System
PI	Principal Investigator
PM	Project Manager
PN	Pseudo Noise
POCC	Payload Operations Control Center
POEM	Polar Orbit Earth Observation Mission
PSCN	Program Support Communications Network
PSK	Phase Shift Key
PSS	Portable Spacecraft Simulator
RADARSAT	Radar Satellite
RF	Radio Frequency
RMA	Reliability, Maintainability and Availability
RT	Real-time
RTS	Relative-Time Sequence
SA	Single Access
SAFIRE	Spectroscopy of the Atmosphere using Far Infrared Emission
SAGE III	Stratospheric Aerosol and Gas Experiment III
S/C	Spacecraft
SCC	Spacecraft Controls Computer
SCF	Science Computing Facility
SDB	Spacecraft Data Base
SMA	S-Band Multiple Access
SMC	System Management Center
SN	Space Network

SOLSTICE	Solar Stellar Irradiance Comparison Experiment
SOM	Systems Operations Manager
SQPN	Staggered Quadri-Phase PN
SSA	S-Band Single Access
SSALT	Solid State Altimeter
SSM	Science Software Manager
STA	Science and Technology Agency
STDN	Spaceflight Tracking and Data Network
TBD	To Be Determined
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TES	Tropospheric Emission Spectrometer
TL	Team Leader
TM	Team Member
TMR	TOPEX Microwave Radiometer
TONS	TDRSS On-board Navigation System
TOO	Target-Of-Opportunity
TOPEX	Ocean Topography Experiment
TRMM	Tropical Rainfall Measuring Mission
TW	Target Week
UARS	Upper Atmosphere Research Satellite
U.S.	United States
USGS	United States Geological Survey
VAFB	Vandenberg Air Force Base
VCID	Virtual Channel Identifier
V0	Version 0
WAN	Wide Area Network
WBDCS	Wide-Band Data Collection System
WSC	White Sands Complex
WOTS	Wallops Orbital Tracking Station

APPENDIX B - GLOSSARY

Ancillary Data	Data other than the instrument data required to operate the instrument or perform data processing. They typically include orbit data, attitude data, time data, other spacecraft engineering data, calibration data, and data quality information
Browse Data Products	Subsets of a larger data set, other than the directory and guide, generated for the purpose of allowing rapid interrogation (i.e., browsing) of the larger data set by a potential user. For example, the browse product of an image data set with multiple spectral bands and moderate spatial resolution might be an image in two spectral channels, at a degraded spatial resolution. The form of the browse data is generally unique for each type of data set and depends on the nature of the data and on the criteria used for data selection within the relevant scientific disciplines..
Calibration Data	Any data required to calibrate an instrument, including subsets of instrument science data, instrument engineering data, spacecraft engineering data, pre-flight instrument calibration measurements, and in-flight ground truth measurements.
Detailed Activity Schedule	The schedule for a spacecraft covering a 7-day period and generated/updated daily based on the instrument activity requests for each of the instruments . The spacecraft subsystem activity requests needed for routine spacecraft operations and/or for supporting instrument activities are also incorporated.
Data Acquisition Request (DAR)	A request for future data acquisition by an instrument(s) that a user constructs and submits through the DAACs.

Data Product Level	A classification of data products by the sort of processing used in their generation and, to a lesser extent, the sort of uses to which these products might be put. The levels described below are consistent with those defined by the EOS Advisory Panel in its report and with CODMAC definitions.
	Raw Data--Data in their original packets as received from the spacecraft, unprocessed by EOSDIS.
	Level 0--Reconstructed, unprocessed instrument data at full space-time resolution, with all available supplemental information to be used in subsequent processing (e.g., ephemeris, health and safety) appended.
	Level 1A - Unpacked, reformatted Level 0 data at full space-time resolution, with all supplemental information to be used in subsequent processing appended.
Data Product Level (Continued)	Level 1B--Radiometrically corrected and calibrated data in physical units at full instrument resolution as acquired.
	Level 1C--Level 1B data that have been spatially resampled.
	Level 2--Retrieved environmental variables (e.g., ocean wave height, soil moisture, or ice concentration) at the same location and similar resolution as the Level 1 source data.
	Level 3-- Data or retrieved environmental variables that have been spatially and/or temporally resampled (i.e., derived from Level 1 or Level 2 data products). Such resampling may include averaging and compositioning.
	Level 4--Model output and/or variables derived from lower level data that are not directly measured by the instruments. For example, new variables based upon a time series of Level 2 or Level 3 data.
Data Set	A logically meaningful grouping or collection of similar or related data.

Engineering Data	Data that describe the physical condition and operation of the instruments (e.g., configuration, memory data, or temperatures).
Housekeeping Telemetry	Information from the spacecraft or instrument that is directly related to its health and safety.
Long-term Instrument Plan	The plan generated by the instrument representative for the spacecraft IWG, with instrument specific information to complement the long-term science plan. It is generated or updated approximately every 6 months and covers a period of up to 5 years.
Long-term Science Plan	The plan generated by the spacecraft IWG containing guidelines, policy, and priorities for the spacecraft. It is generated or updated approximately every 6 months and covers a period of approximately 5 years.
Metadata	Descriptive information pertaining to data sets. This includes data set descriptions in directories, guides, and inventories plus any additional information that defines the relationships among them.
Playback Data (Tape Recorded Data)	Data that are stored on the spacecraft tape recorders for delayed transmission to the ground.
Rate-Buffered Data	Raw, real-time or playback unprocessed packet data; done on a TDRS session or ground station basis and delivered by EDOS on an expedited basis.
Real-time Data	Data that are acquired by the instrument and spacecraft data system and transmitted directly to the ground.
Special Data Products	Data products that are generated as part of a research investigation using EOS data and that are produced for a limited region or time period, or products that are not accepted as standard by the EOS IWG and NASA Headquarters are referred to as special data products. Special data products will normally be generated at investigator SCFs. Special products may be reclassified later as standard products upon review and approval by the EOS IWG and NASA Headquarters; in which case the algorithms and processing will migrate to the PGS and be placed under the appropriate configuration controls.

Standard Data Products	Data products that are generated as part of a research investigation using EOS data, are of wide research utility, are routinely generated, and in general are produced for spatially and/or temporarily extensive subsets of the data are to be considered standard data products. All EOS instruments must have standard Level 1 data products, and most will have standard Level 2 data products. Some EOS Interdisciplinary Investigations will also generate standard data products. Specifications for the set of standard data products to be generated by the EOS IWG and NASA Headquarters to ensure completeness and consistency in providing a comprehensive science data output for the EOS mission.
Target of Opportunity (TOO)	A TOO is an event or phenomenon that occurs without warning. It therefore cannot be fully planned and scheduled in advance, thus requiring timely system response or high-priority processing. An event that requires a change only to a long-term plan is not considered a TOO because it can be handled without perturbing the scheduling system.
Telemetry	A space-to-ground data stream of measured values (including instrument science data, instrument engineering data, and spacecraft engineering data) that does not include command, tracking, computer memory transfer, audio, or video signals.